US009148389B2

(12) **United States Patent**
Jacob Da Silva et al.

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(45) **Date of Patent:** **Sep. 29, 2015**

(54) **SYSTEM AND METHOD FOR A VIRTUAL CHASSIS SYSTEM**

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(73) Assignee: **Alcatel Lucent**, Boulogne-Billiancourt (FR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 394 days.

(21) Appl. No.: **13/674,259**

(22) Filed: **Nov. 12, 2012**

(65) **Prior Publication Data**

US 2013/0077621 A1 Mar. 28, 2013

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/010,168, filed on Jan. 20, 2011, now Pat. No. 8,767,735.

(60) Provisional application No. 61/370,622, filed on Aug. 4, 2010, provisional application No. 61/658,159, filed on Jun. 11, 2012.

(51) **Int. Cl.**

H04L 12/939	(2013.01)
H04L 12/775	(2013.01)
H04L 12/709	(2013.01)
H04L 12/931	(2013.01)
H04L 12/707	(2013.01)
H04L 12/703	(2013.01)

(52) **U.S. Cl.**

CPC ***H04L 49/552*** (2013.01); ***H04L 45/245*** (2013.01); ***H04L 45/58*** (2013.01); ***H04L 49/40*** (2013.01); ***H04L 49/70*** (2013.01); *H04L 45/22* (2013.01); *H04L 45/28* (2013.01)

(58) **Field of Classification Search**

CPC H04L 49/70; H04L 45/586; H04L 45/583; H04L 45/58; H04L 49/357; H04L 45/245

See application file for complete search history.

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2011/0149743	A1*	6/2011	Agarwal et al.	370/242
2013/0243008	A1*	9/2013	Singla et al.	370/422

* cited by examiner

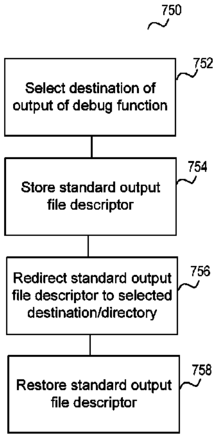
Primary Examiner — Jung Park

(74) *Attorney, Agent, or Firm* — Loza & Loza, LLP

(57) **ABSTRACT**

A virtual chassis system includes a plurality of network nodes configured with a master virtual chassis address. The network nodes are connected by virtual fabric link (VFLs) that provide a connection for exchange of packets between the network nodes. The packets include source MAC addresses and associated hardware device information, such as source chassis ID, source network interface identifier and source port identifier information. The network nodes use this information to maintain synchronized MAC address tables for forwarding of packets in the virtual chassis system.

13 Claims, 16 Drawing Sheets


750
Select destination of output of debug function
752
Store standard output file descriptor
754
Redirect standard output file descriptor to selected destination/directory
756
Restore standard output file descriptor
758

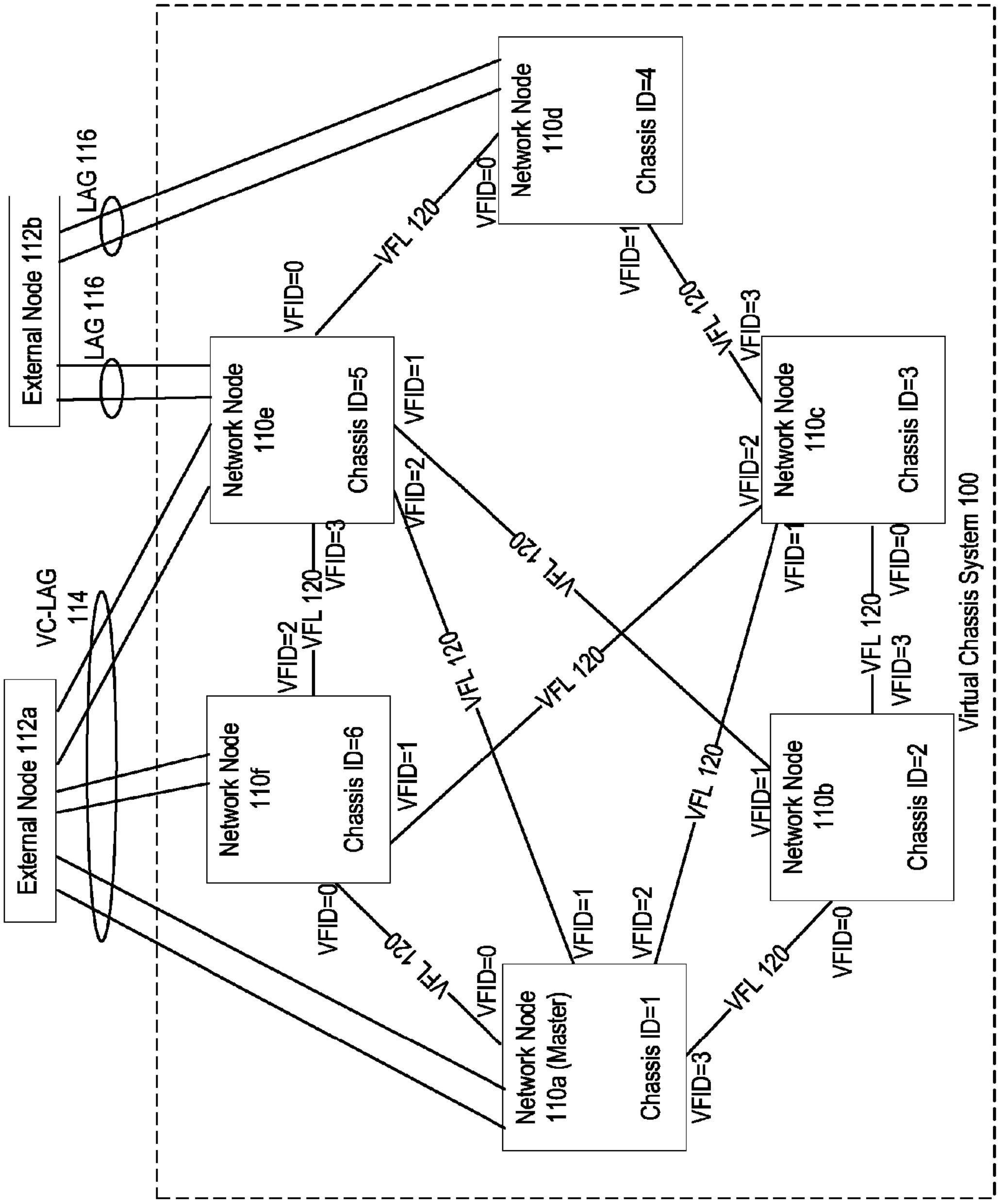

External Node 112b
LAG 116
LAG 116
External Node 112a
VC-LAG 114
Network Node 110d
Chassis ID=4
Network Node 110e
Chassis ID=5
Network Node 110c
Chassis ID=3
Network Node 110f
Chassis ID=6
Network Node 110b
Chassis ID=2
Network Node 110a (Master)
Chassis ID=1
VFL 120
VFL 120
VFL 120
VFL 120
VFL 120
VFL 120
VFL 120
VFL 120
VFL 120
VFL 120
VFID=0
VFID=0
VFID=1
VFID=3
VFID=1
VFID=2
VFID=3
VFID=2
VFID=2
VFID=1
VFID=0
VFID=3
VFID=1
VFID=1
VFID=0
VFID=0
VFID=1
VFID=2
VFID=3
VFID=0
Virtual Chassis System 100

Fig. 1a

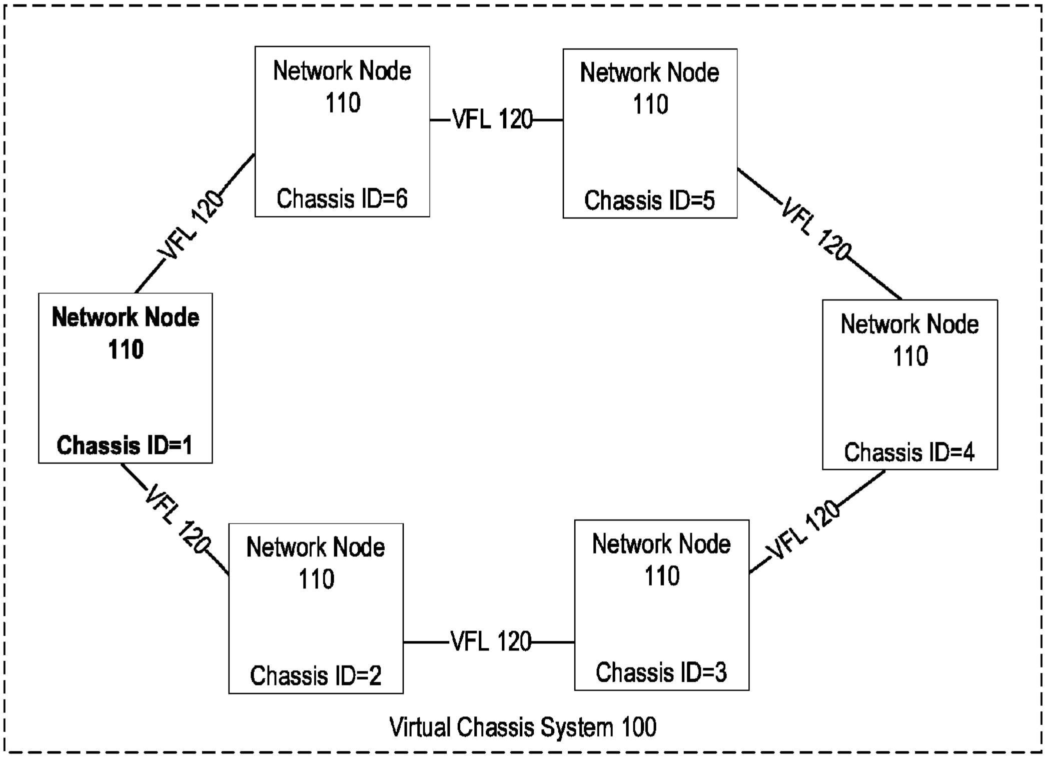

Network Node 110
Chassis ID=6
VFL 120
Network Node 110
Chassis ID=5
VFL 120
VFL 120
Network Node 110
Chassis ID=1
Network Node 110
Chassis ID=4
VFL 120
VFL 120
Network Node 110
Chassis ID=2
VFL 120
Network Node 110
Chassis ID=3
Virtual Chassis System 100

Fig. 1b

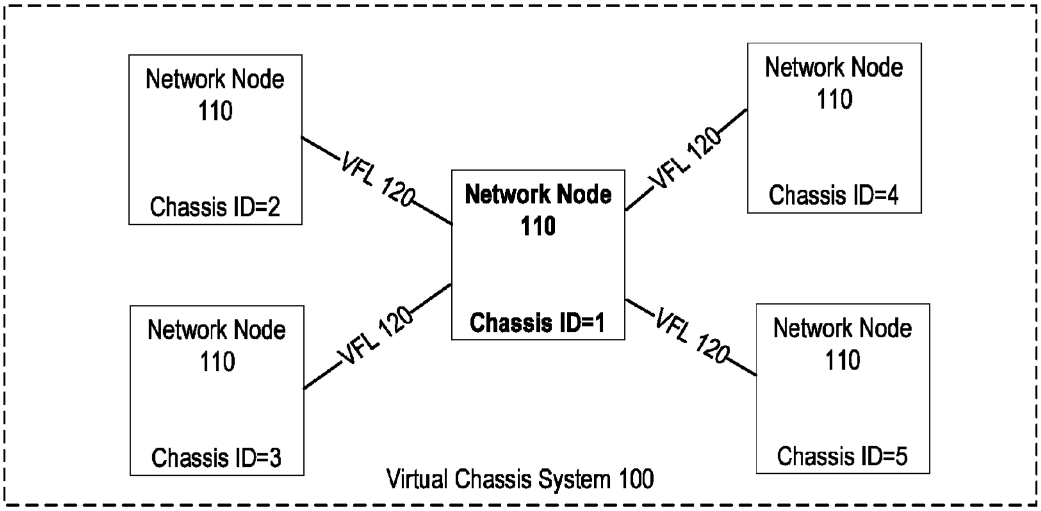

Network Node 110
Chassis ID=2
VFL 120
Network Node 110
Chassis ID=1
VFL 120
Network Node 110
Chassis ID=4
Network Node 110
Chassis ID=3
VFL 120
VFL 120
Network Node 110
Chassis ID=5
Virtual Chassis System 100

Fig. 1c

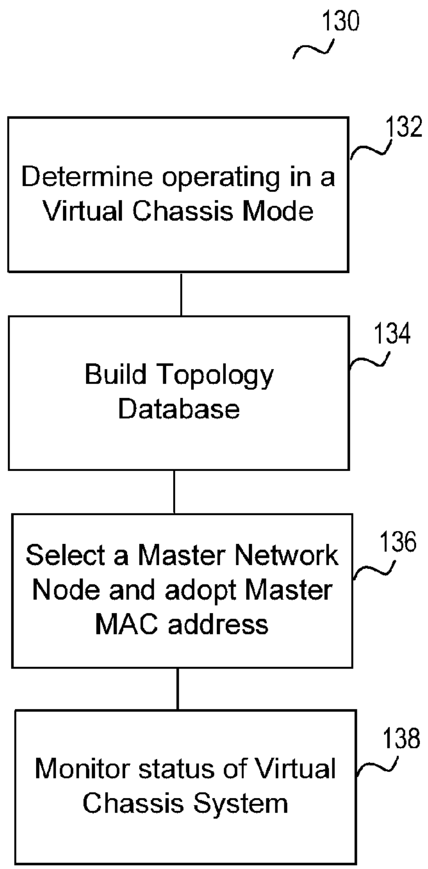

130
Determine operating in a Virtual Chassis Mode
132
Build Topology Database
134
Select a Master Network Node and adopt Master MAC address
136
Monitor status of Virtual Chassis System
138

Fig. 2

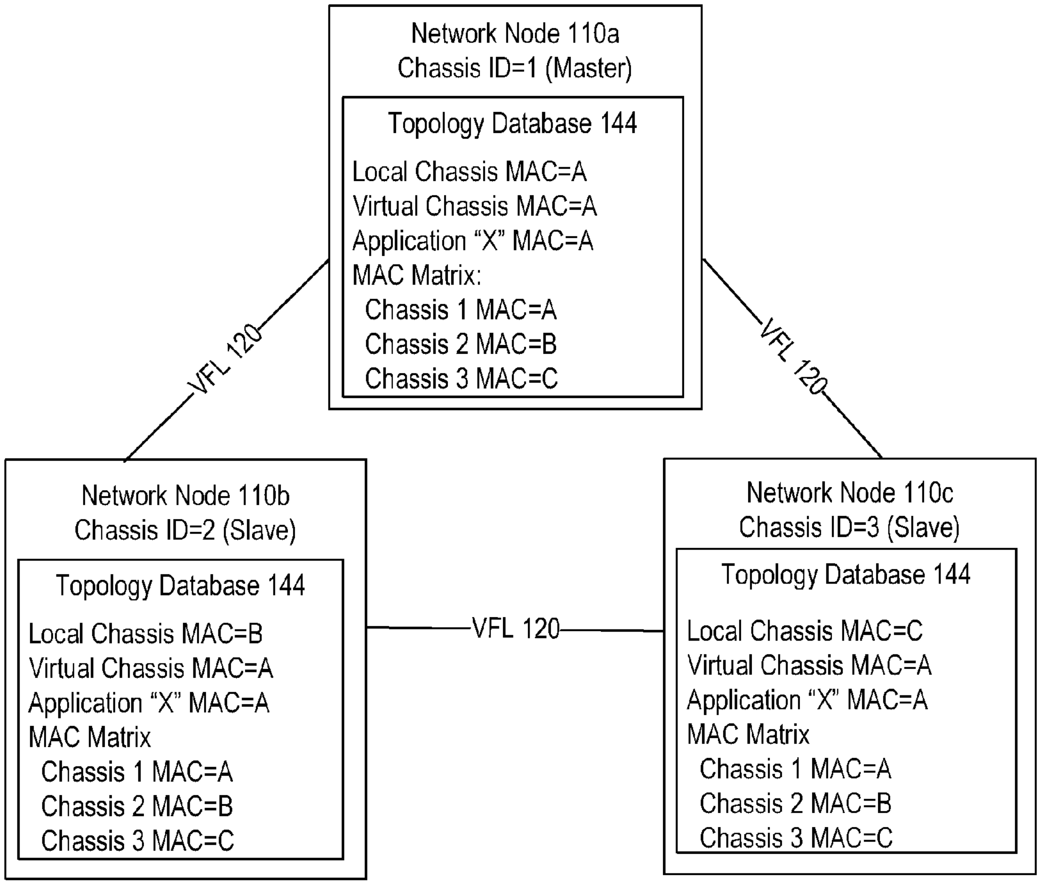

Network Node 110a
Chassis ID=1 (Master)
Topology Database 144
Local Chassis MAC=A
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix:
Chassis 1 MAC=A
Chassis 2 MAC=B
Chassis 3 MAC=C
VFL 120
VFL 120
Network Node 110b
Chassis ID=2 (Slave)
Topology Database 144
Local Chassis MAC=B
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix
Chassis 1 MAC=A
Chassis 2 MAC=B
Chassis 3 MAC=C
VFL 120
Network Node 110c
Chassis ID=3 (Slave)
Topology Database 144
Local Chassis MAC=C
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix
Chassis 1 MAC=A
Chassis 2 MAC=B
Chassis 3 MAC=C

Fig. 3

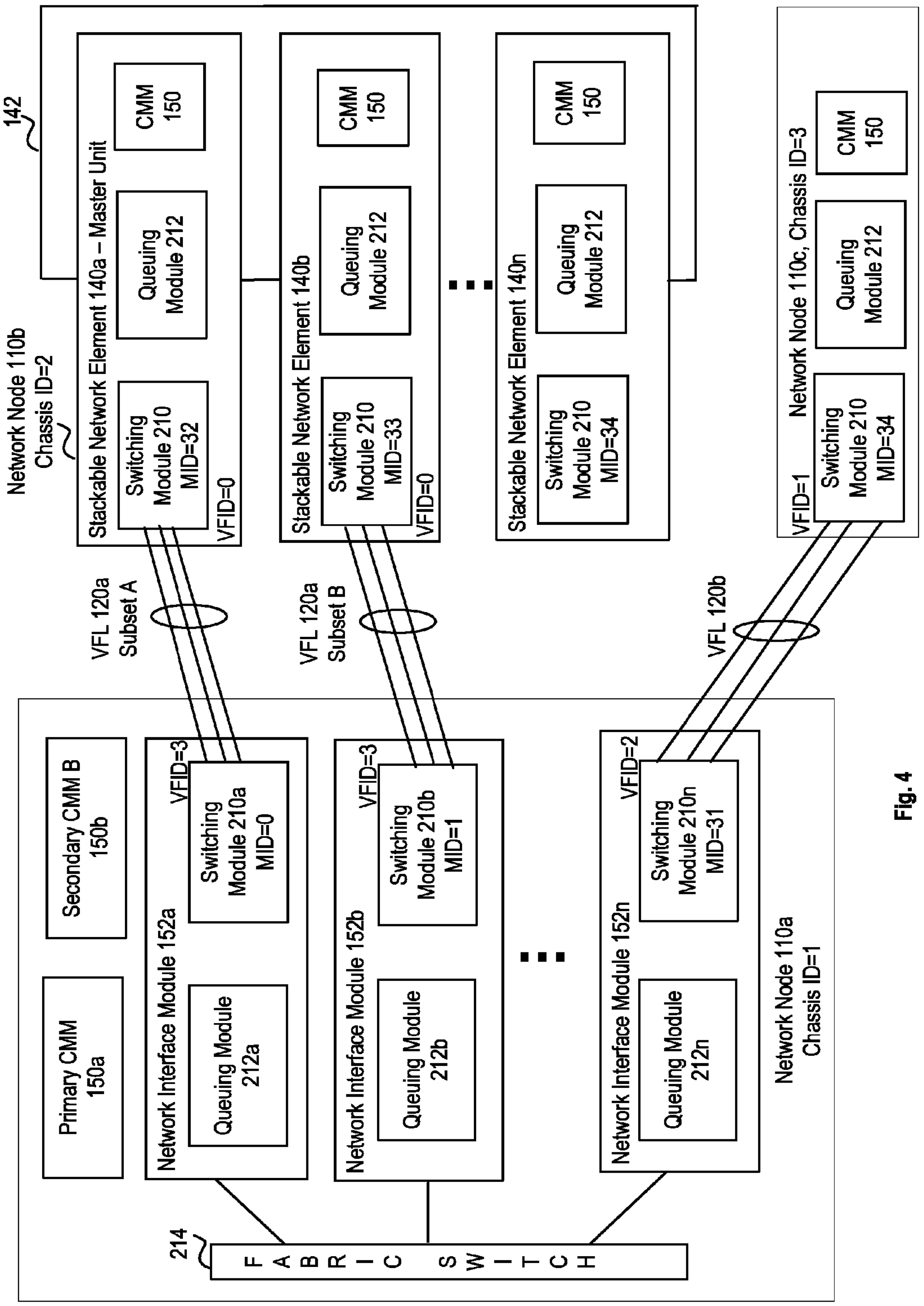

142
Network Node 110b
Chassis ID=2
Stackable Network Element 140a – Master Unit
Switching Module 210
MID=32
Queuing Module 212
CMM 150
VFID=0
Stackable Network Element 140b
Switching Module 210
MID=33
Queuing Module 212
CMM 150
VFID=0
Stackable Network Element 140n
Switching Module 210
MID=34
Queuing Module 212
CMM 150
Network Node 110c, Chassis ID=3
VFID=1
Switching Module 210
MID=34
Queuing Module 212
CMM 150
VFL 120a
Subset A
VFL 120a
Subset B
VFL 120b
Primary CMM
150a
Secondary CMM B
150b
Network Interface Module 152a
Queuing Module
212a
VFID=3
Switching
Module 210a
MID=0
Network Interface Module 152b
Queuing Module
212b
VFID=3
Switching
Module 210b
MID=1
Network Interface Module 152n
Queuing Module
212n
VFID=2
Switching
Module 210n
MID=31
Network Node 110a
Chassis ID=1
214
FABRIC SWITCH

Fig. 4

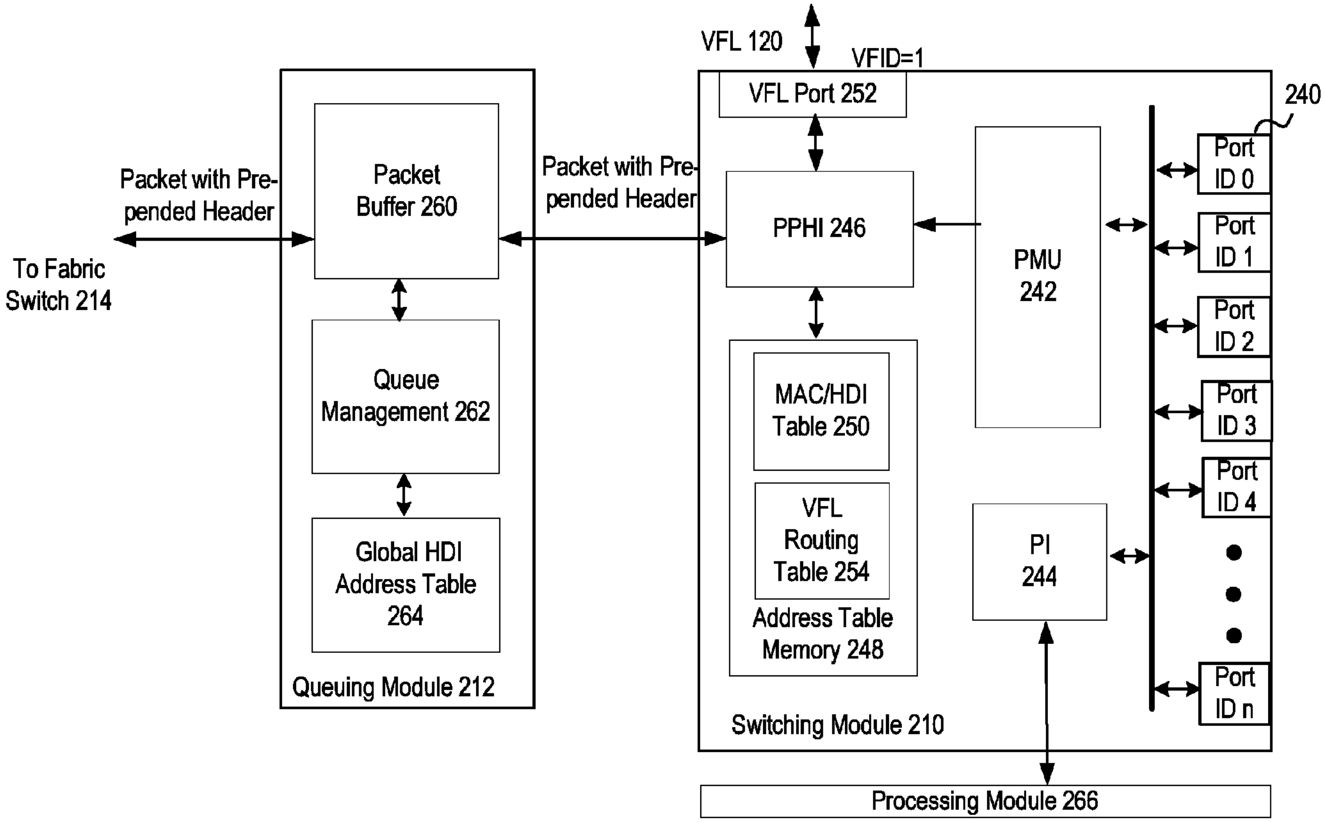

VFL 120
VFID=1
VFL Port 252
240
To Fabric Switch 214
Packet with Pre-pended Header
Packet Buffer 260
Queue Management 262
Global HDI Address Table 264
Queuing Module 212
Packet with Pre-pended Header
PPHI 246
PMU 242
MAC/HDI Table 250
VFL Routing Table 254
Address Table Memory 248
PI 244
Port ID 0
Port ID 1
Port ID 2
Port ID 3
Port ID 4
Port ID n
Switching Module 210
Processing Module 266

Fig. 5

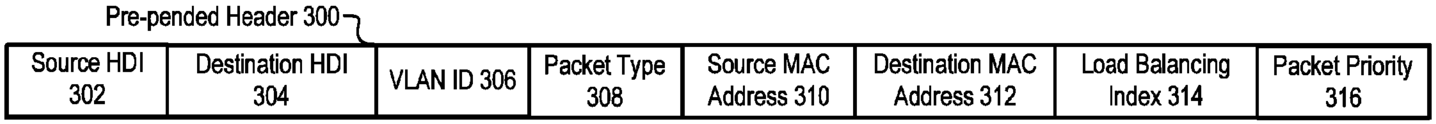
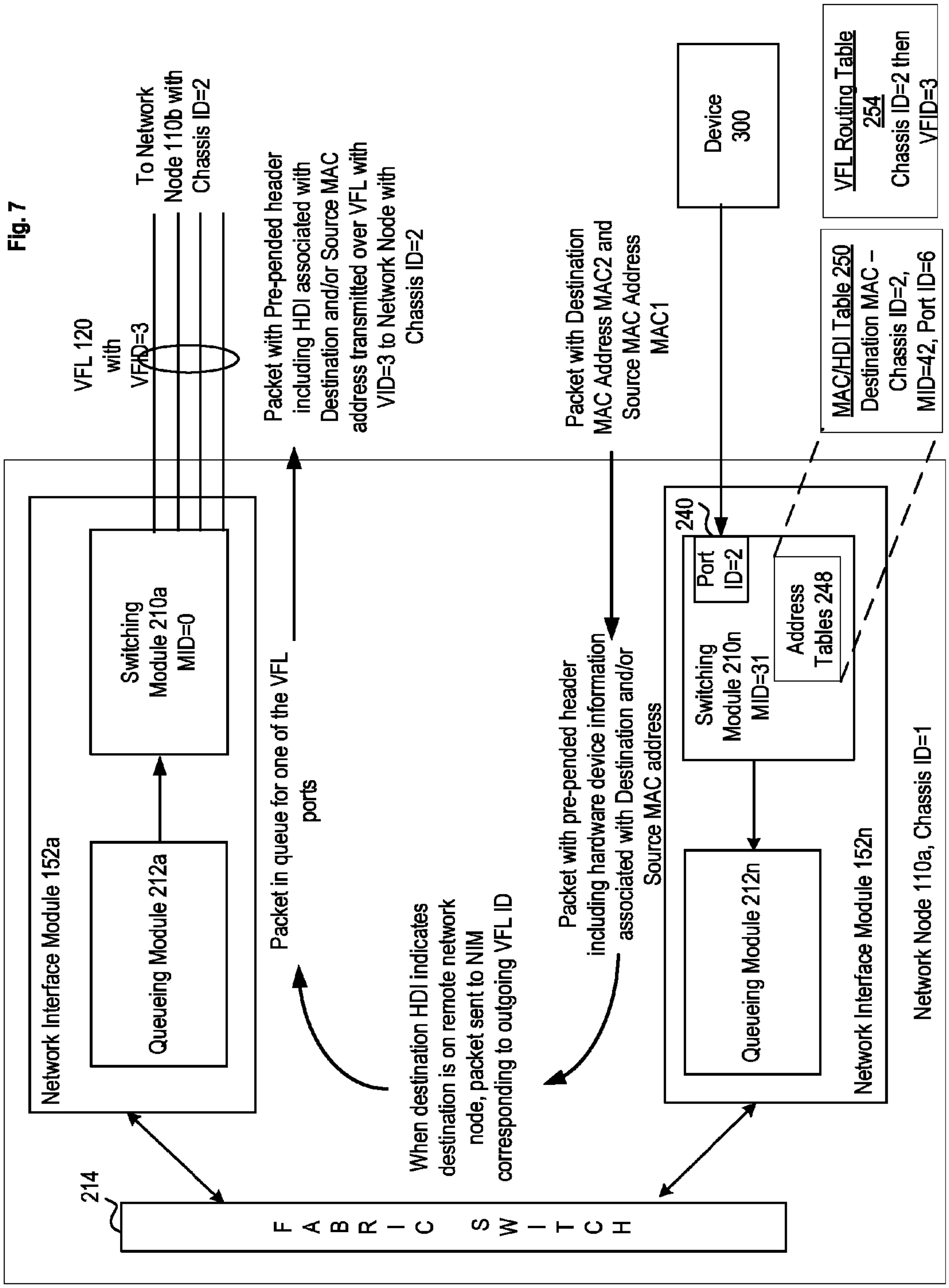

Pre-pended Header 300
Source HDI 302
Destination HDI 304
VLAN ID 306
Packet Type 308
Source MAC Address 310
Destination MAC Address 312
Load Balancing Index 314
Packet Priority 316

Fig. 6

Fig. 7


VFL 120
with
VFID=3
To Network
Node 110b with
Chassis ID=2
Packet with Pre-pended header
including HDI associated with
Destination and/or Source MAC
address transmitted over VFL with
VID=3 to Network Node with
Chassis ID=2
Packet with Destination
MAC Address MAC2 and
Source MAC Address
MAC1
Device
300
VFL Routing Table
254
Chassis ID=2 then
VFID=3
MAC/HDI Table 250
Destination MAC –
Chassis ID=2,
MID=42, Port ID=6
Network Interface Module 152a
Queueing Module 212a
Switching
Module 210a
MID=0
Packet in queue for one of the VFL
ports
When destination HDI indicates
destination is on remote network
node, packet sent to NIM
corresponding to outgoing VFL ID
Packet with pre-pended header
including hardware device information
associated with Destination and/or
Source MAC address
240
Port
ID=2
Address
Tables 248
Switching
Module 210n
MID=31
Queueing Module 212n
Network Interface Module 152n
Network Node 110a, Chassis ID=1
214
FABRIC SWITCH

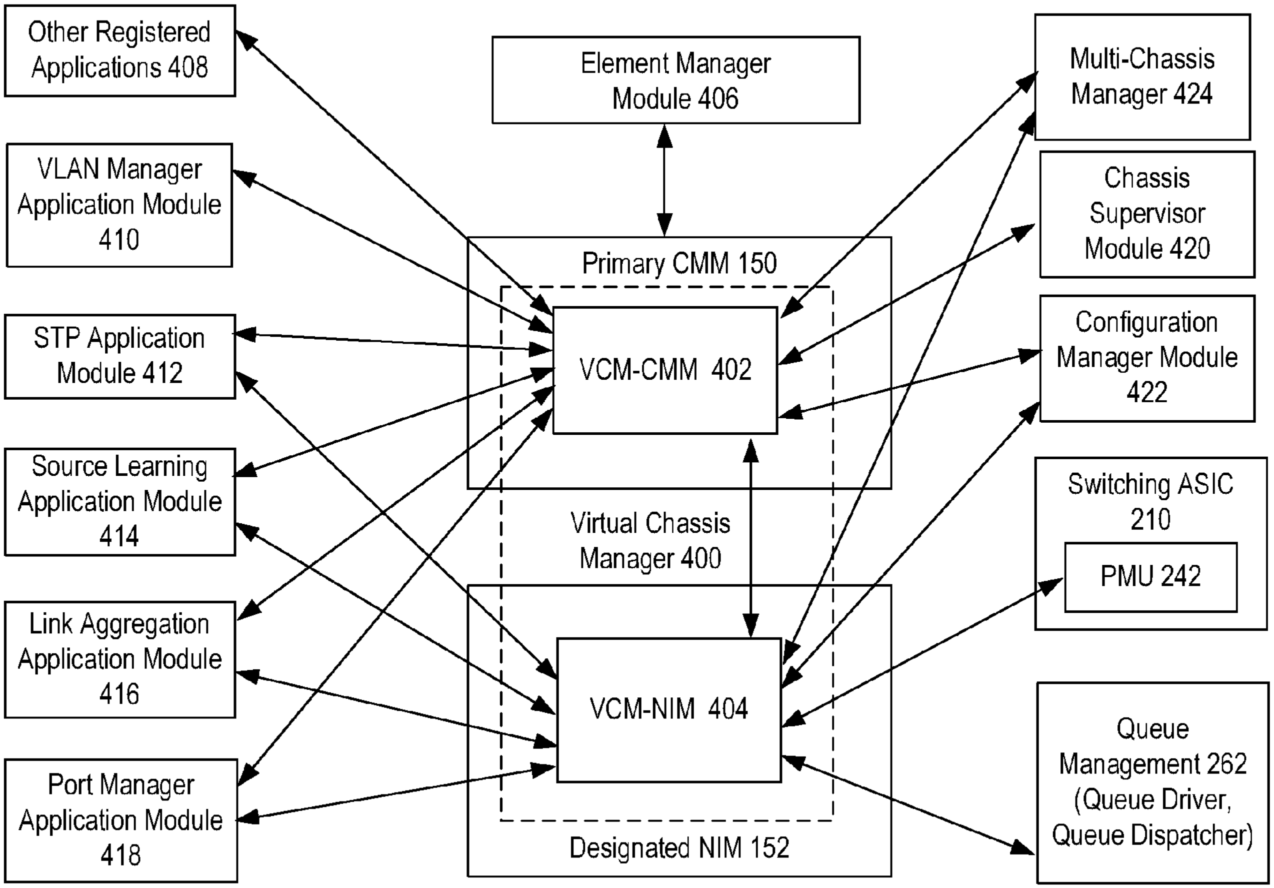

Other Registered Applications 408
VLAN Manager Application Module 410
STP Application Module 412
Source Learning Application Module 414
Link Aggregation Application Module 416
Port Manager Application Module 418
Element Manager Module 406
Primary CMM 150
VCM-CMM 402
Virtual Chassis Manager 400
VCM-NIM 404
Designated NIM 152
Multi-Chassis Manager 424
Chassis Supervisor Module 420
Configuration Manager Module 422
Switching ASIC 210
PMU 242
Queue Management 262 (Queue Driver, Queue Dispatcher)

Fig. 8

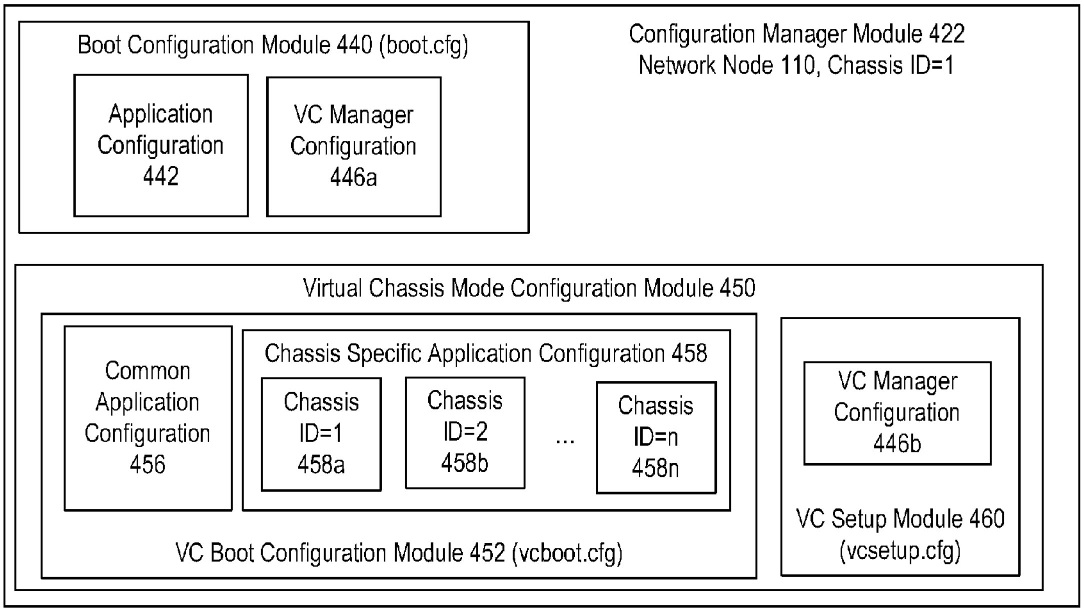

Boot Configuration Module 440 (boot.cfg)
Application Configuration 442
VC Manager Configuration 446a
Configuration Manager Module 422
Network Node 110, Chassis ID=1
Virtual Chassis Mode Configuration Module 450
Common Application Configuration 456
Chassis Specific Application Configuration 458
Chassis ID=1 458a
Chassis ID=2 458b
...
Chassis ID=n 458n
VC Boot Configuration Module 452 (vcboot.cfg)
VC Manager Configuration 446b
VC Setup Module 460 (vcsetup.cfg)

Fig. 9

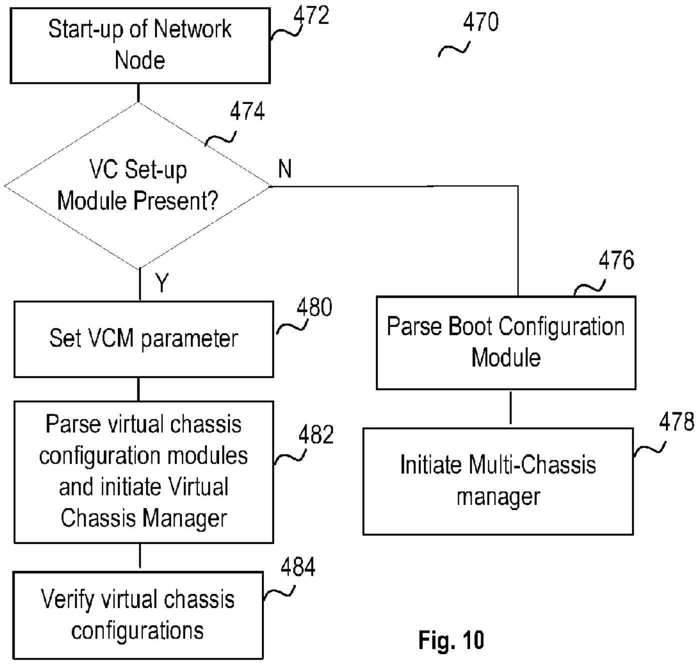

Start-up of Network Node
472
470
474
VC Set-up Module Present?
N
Y
476
Parse Boot Configuration Module
478
Initiate Multi-Chassis manager
480
Set VCM parameter
482
Parse virtual chassis configuration modules and initiate Virtual Chassis Manager
484
Verify virtual chassis configurations

Fig. 10

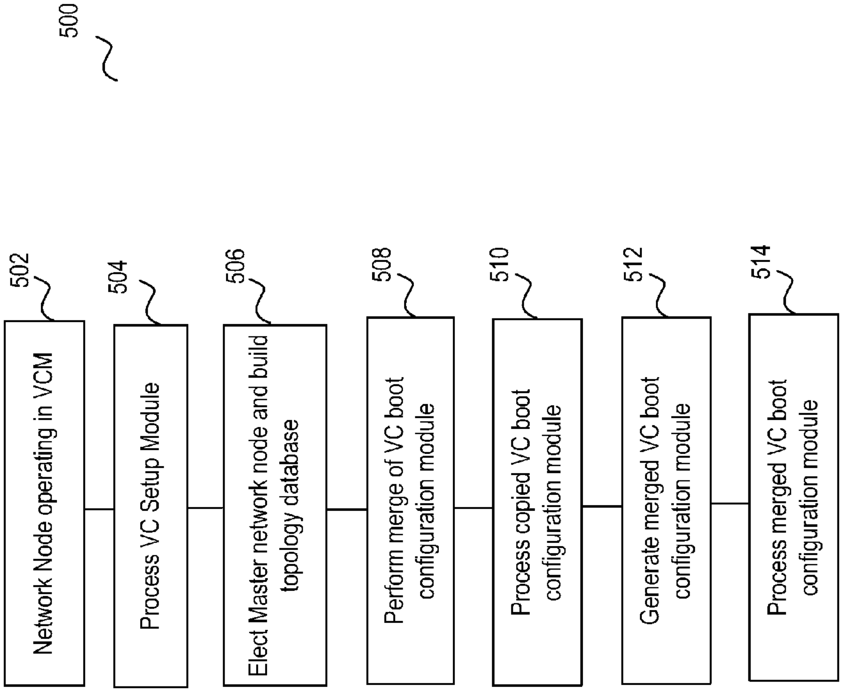

500
502
Network Node operating in VCM
504
Process VC Setup Module
506
Elect Master network node and build topology database
508
Perform merge of VC boot configuration module
510
Process copied VC boot configuration module
512
Generate merged VC boot configuration module
514
Process merged VC boot configuration module

Fig. 11

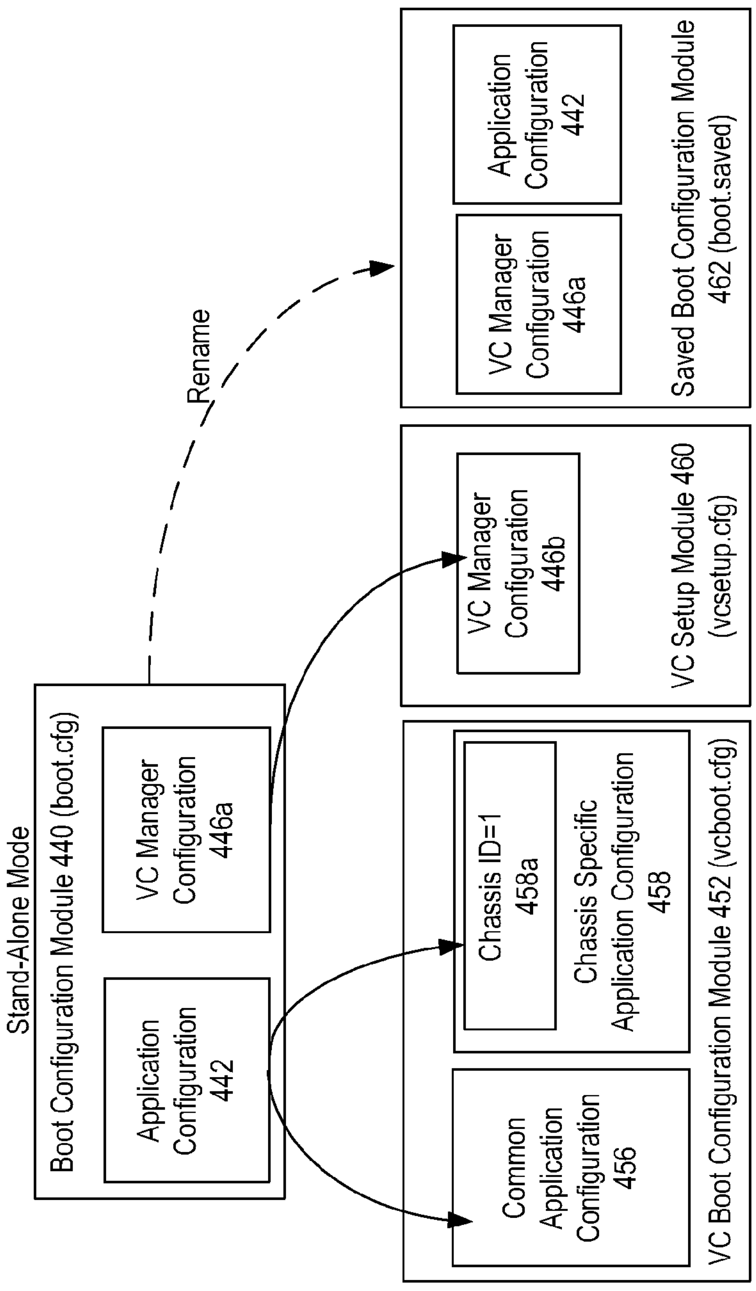

Stand-Alone Mode
Boot Configuration Module 440 (boot.cfg)
Application Configuration 442
VC Manager Configuration 446a
Rename
Common Application Configuration 456
Chassis ID=1 458a
Chassis Specific Application Configuration 458
VC Boot Configuration Module 452 (vcboot.cfg)
Virtual Chassis Mode
VC Manager Configuration 446b
VC Setup Module 460 (vcsetup.cfg)
VC Manager Configuration 446a
Application Configuration 442
Saved Boot Configuration Module 462 (boot.saved)

Fig. 12

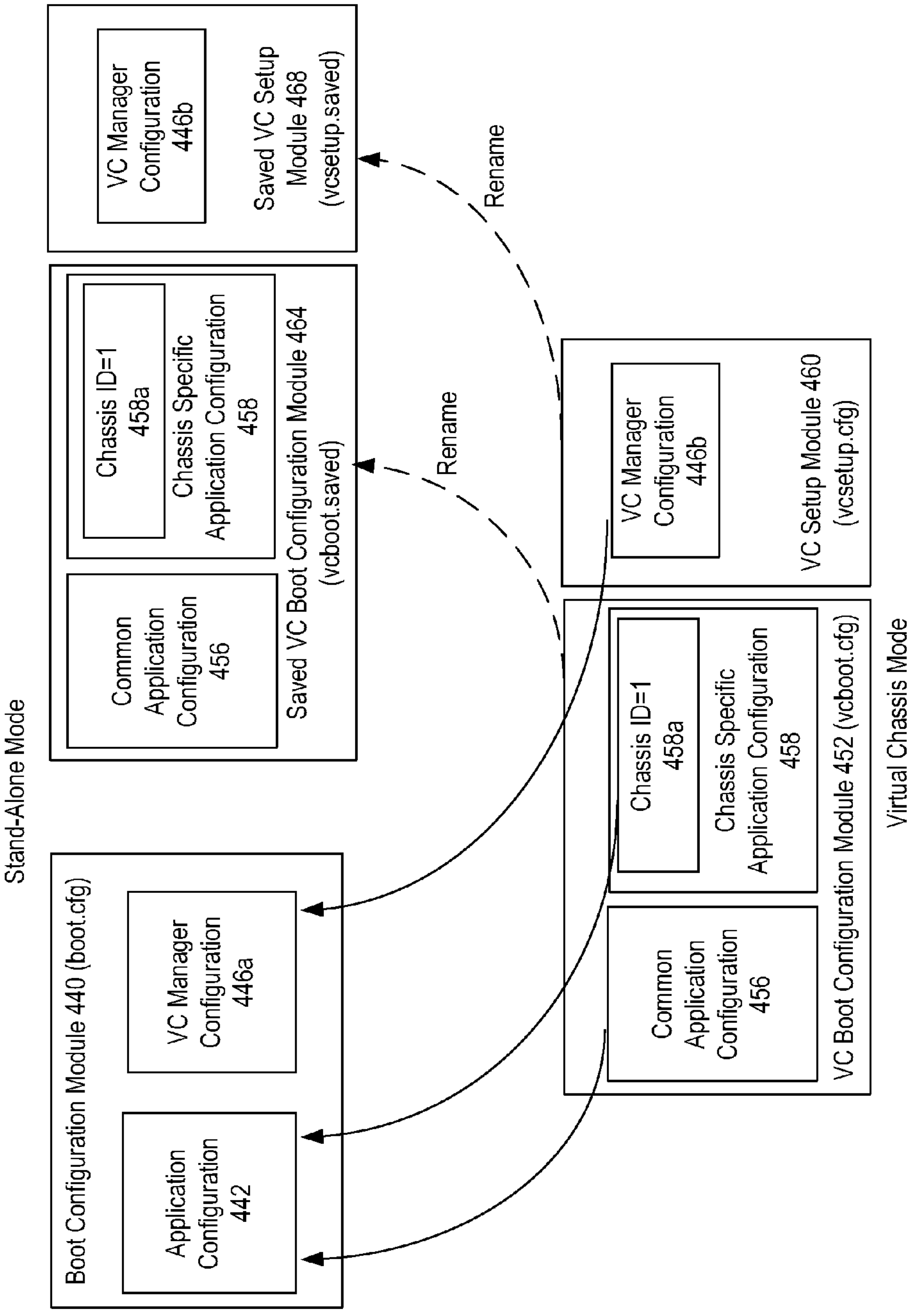

Stand-Alone Mode
Boot Configuration Module 440 (boot.cfg)
Application Configuration 442
VC Manager Configuration 446a
Common Application Configuration 456
Chassis ID=1 458a
Chassis Specific Application Configuration 458
Saved VC Boot Configuration Module 464 (vcboot.saved)
VC Manager Configuration 446b
Saved VC Setup Module 468 (vcsetup.saved)
Rename
Rename
Common Application Configuration 456
Chassis ID=1 458a
Chassis Specific Application Configuration 458
VC Boot Configuration Module 452 (vcboot.cfg)
VC Manager Configuration 446b
VC Setup Module 460 (vcsetup.cfg)
Virtual Chassis Mode

Fig. 13

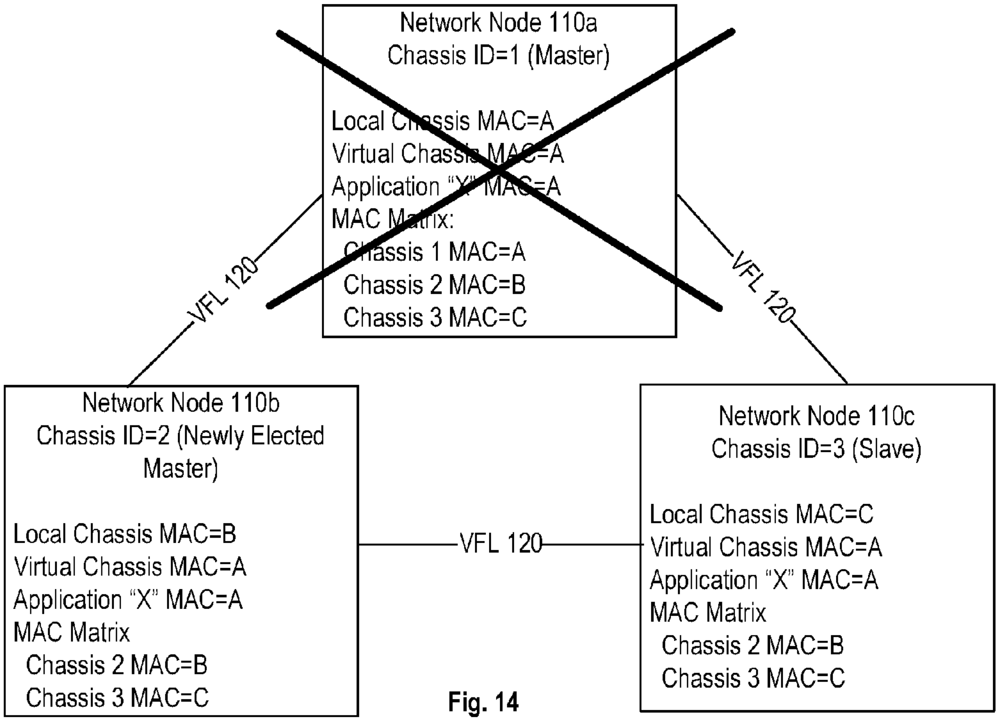

Network Node 110a
Chassis ID=1 (Master)
Local Chassis MAC=A
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix:
Chassis 1 MAC=A
Chassis 2 MAC=B
Chassis 3 MAC=C
VFL 120
VFL 120
Network Node 110b
Chassis ID=2 (Newly Elected Master)
Local Chassis MAC=B
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix
Chassis 2 MAC=B
Chassis 3 MAC=C
VFL 120
Network Node 110c
Chassis ID=3 (Slave)
Local Chassis MAC=C
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix
Chassis 2 MAC=B
Chassis 3 MAC=C

Fig. 14

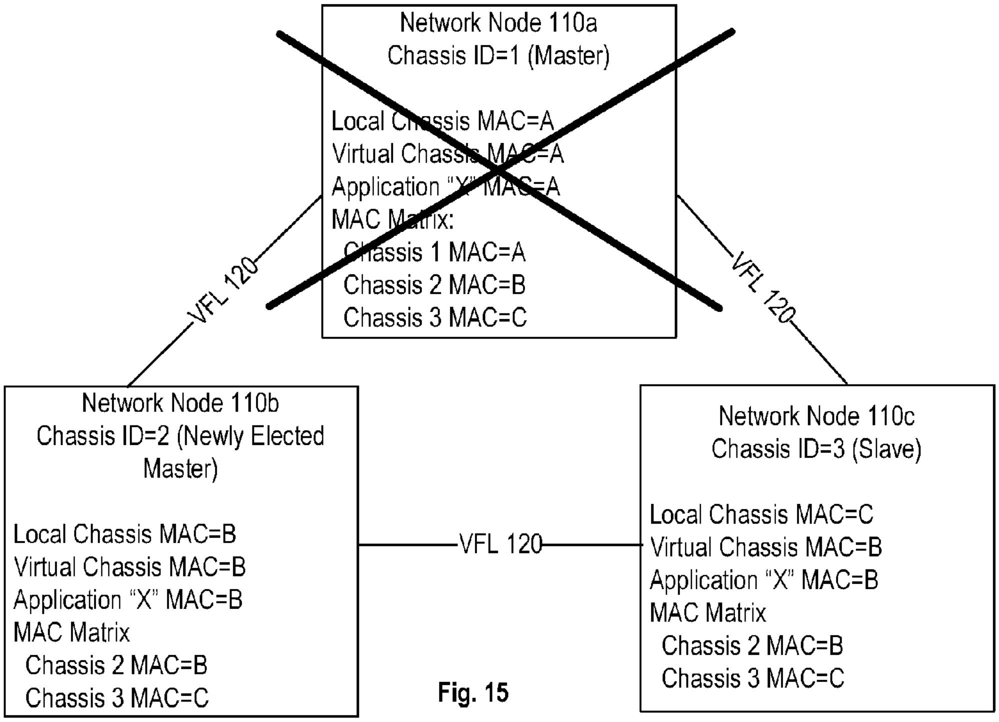

Network Node 110a
Chassis ID=1 (Master)
Local Chassis MAC=A
Virtual Chassis MAC=A
Application "X" MAC=A
MAC Matrix:
Chassis 1 MAC=A
Chassis 2 MAC=B
Chassis 3 MAC=C
VFL 120
VFL 120
Network Node 110b
Chassis ID=2 (Newly Elected Master)
Local Chassis MAC=B
Virtual Chassis MAC=B
Application "X" MAC=B
MAC Matrix
Chassis 2 MAC=B
Chassis 3 MAC=C
VFL 120
Network Node 110c
Chassis ID=3 (Slave)
Local Chassis MAC=C
Virtual Chassis MAC=B
Application "X" MAC=B
MAC Matrix
Chassis 2 MAC=B
Chassis 3 MAC=C

Fig. 15

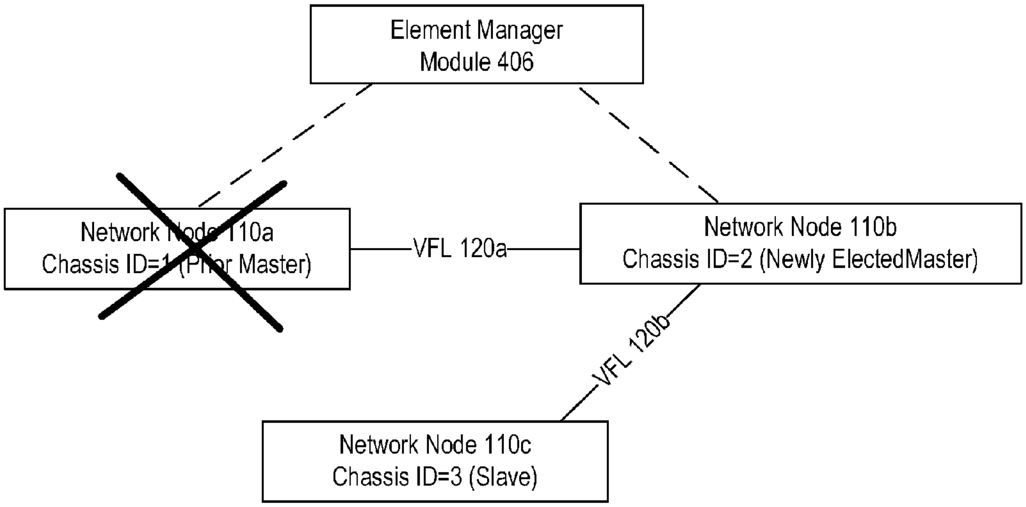

Element Manager
Module 406
Network Node 110a
Chassis ID=1 (Prior Master)
VFL 120a
Network Node 110b
Chassis ID=2 (Newly ElectedMaster)
VFL 120b
Network Node 110c
Chassis ID=3 (Slave)

Fig. 16

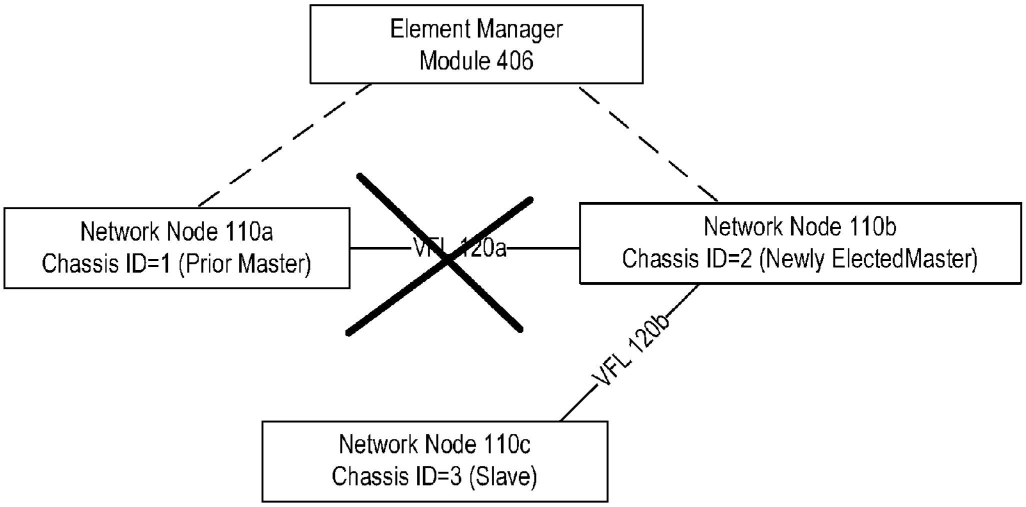

Element Manager
Module 406
Network Node 110a
Chassis ID=1 (Prior Master)
VFL 120a
Network Node 110b
Chassis ID=2 (Newly ElectedMaster)
VFL 120b
Network Node 110c
Chassis ID=3 (Slave)

Fig. 17

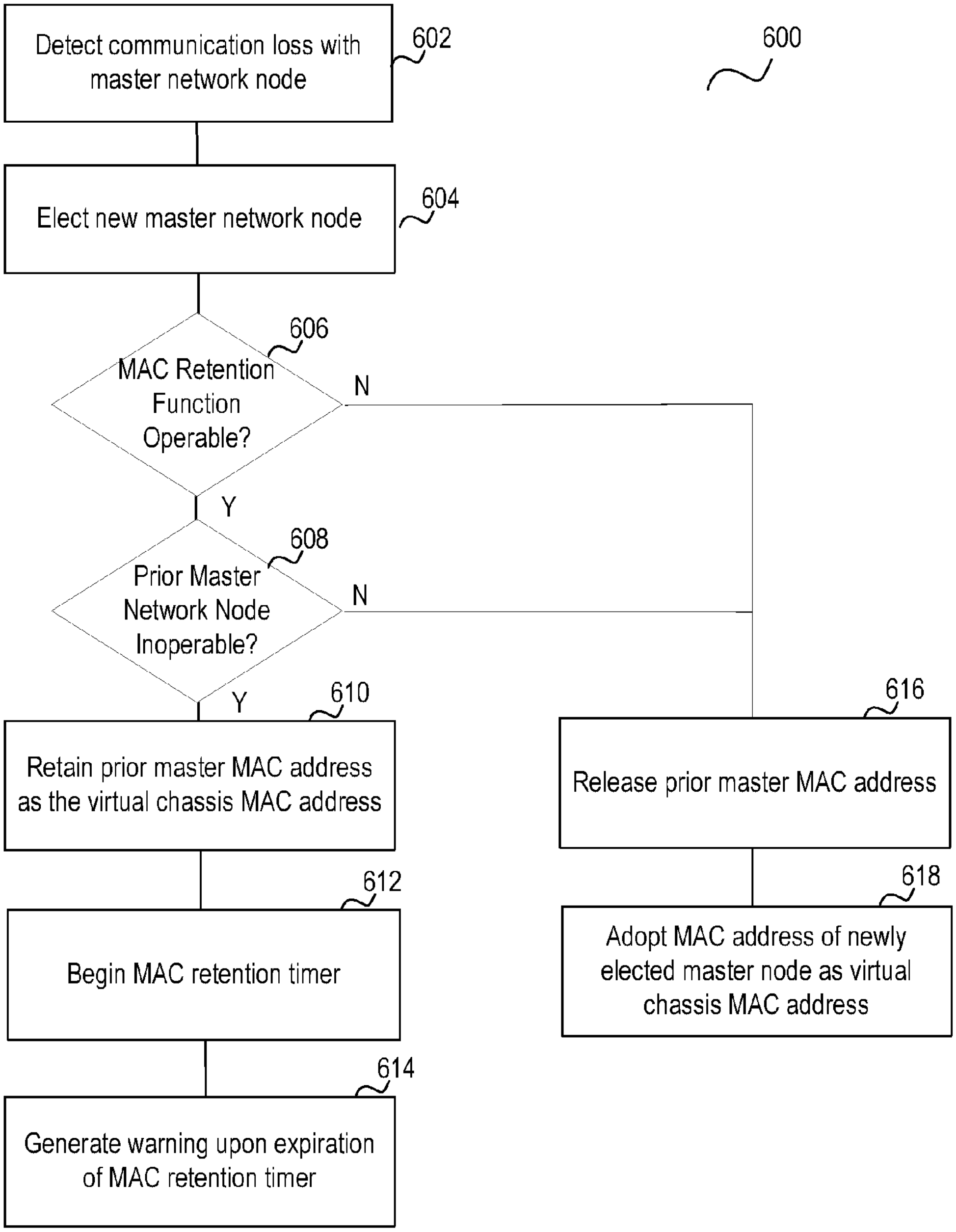
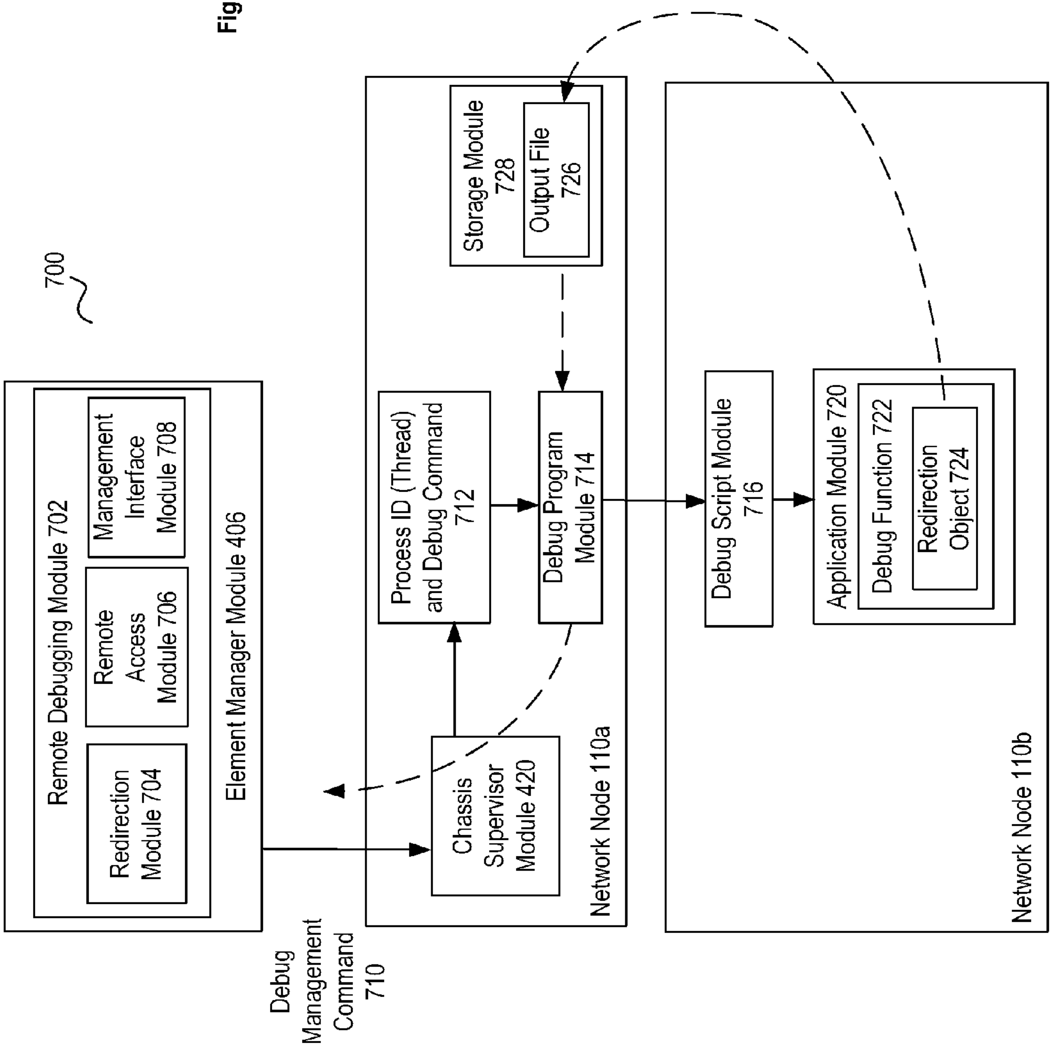

600
Detect communication loss with master network node
602
Elect new master network node
604
MAC Retention Function Operable?
606
N
Y
Prior Master Network Node Inoperable?
608
N
Y
Retain prior master MAC address as the virtual chassis MAC address
610
Begin MAC retention timer
612
Generate warning upon expiration of MAC retention timer
614
Release prior master MAC address
616
Adopt MAC address of newly elected master node as virtual chassis MAC address
618

Fig. 18

Fig. 19


700
Remote Debugging Module 702
Redirection Module 704
Remote Access Module 706
Management Interface Module 708
Element Manager Module 406
Debug Management Command 710
Chassis Supervisor Module 420
Process ID (Thread) and Debug Command 712
Debug Program Module 714
Storage Module 728
Output File 726
Network Node 110a
Debug Script Module 716
Application Module 720
Debug Function 722
Redirection Object 724
Network Node 110b

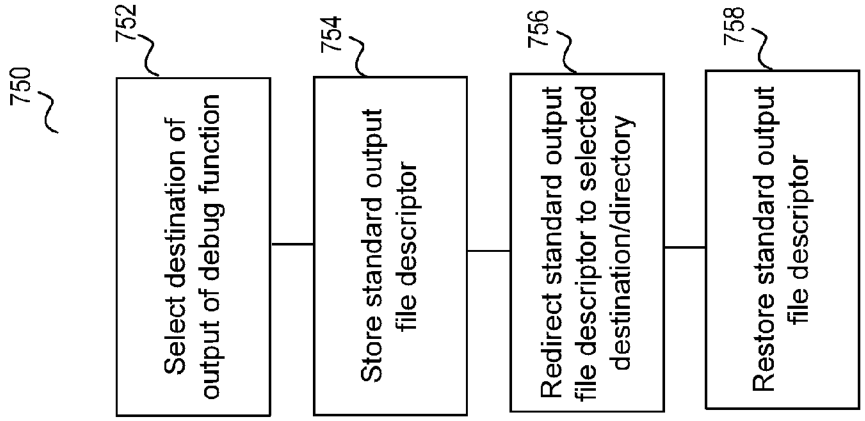

750
752
Select destination of output of debug function
754
Store standard output file descriptor
756
Redirect standard output file descriptor to selected destination/directory
758
Restore standard output file descriptor

Fig. 20

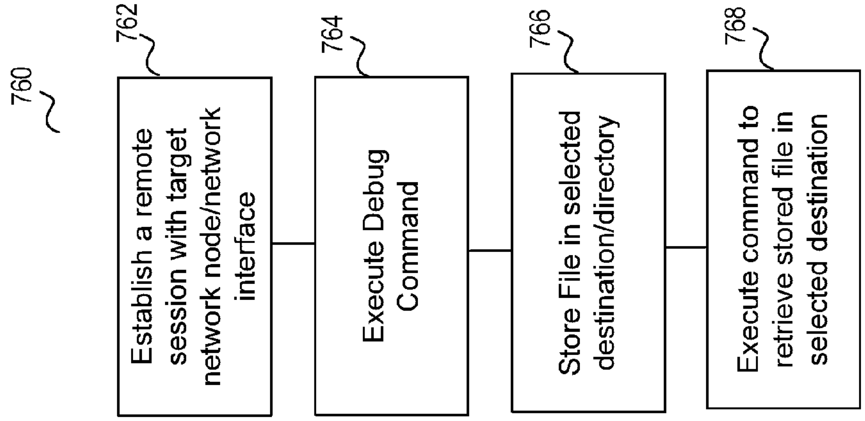

760
762
Establish a remote session with target network node/network interface
764
Execute Debug Command
766
Store File in selected destination/directory
768
Execute command to retrieve stored file in selected destination

Fig. 21

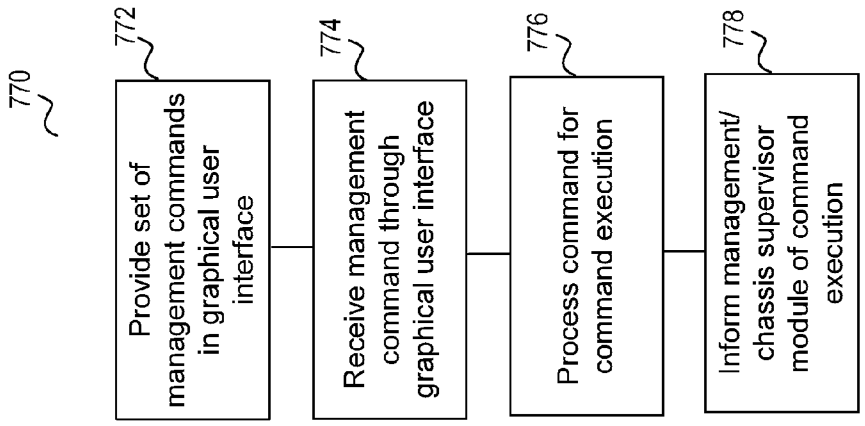

770
772
Provide set of management commands in graphical user interface
774
Receive management command through graphical user interface
776
Process command for command execution
778
Inform management/ chassis supervisor module of command execution

Fig. 22

SYSTEM AND METHOD FOR A VIRTUAL CHASSIS SYSTEM

CROSS-REFERENCE TO RELATED PATENTS

The present U.S. Utility Patent Application claims priority as a continuation in part pursuant to 35 U.S.C. §120 to U.S. patent application Ser. No. 13/010,168, entitled, "SYSTEM AND METHOD FOR MULTI-CHASSIS LINK AGGREGATION," filed Jan. 20, 2011, now issued as U.S. Pat. No. 8,767,735, on Jul. 1, 2014, which is incorporated by reference herein and made part of the present U.S. Utility Patent Application for all purposes and which claims priority pursuant to 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/370,622, entitled, "MULTICHASSIS VIRTUAL-FABRIC LINK AGGREGATION SYSTEM," filed Aug. 4, 2010, which is incorporated by reference herein and made part of the present U.S. Utility Patent Application for all purposes.

The present U.S. Utility Patent Application claims priority pursuant to 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/658,159, entitled, "VIRTUAL CHASSIS WITH GENERIC NODE ARCHITECTURE AND TOPOLOGY," filed Jun. 11, 2012, which is incorporated by reference herein and made part of the present U.S. Utility Patent Application for all purposes.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not applicable.

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

This invention relates generally to data networks and in particular to systems and methods for providing topological redundancy and resiliency between nodes of one or more data networks.

2. Description of Related Art

Data networks include various computing devices, for example, personal computers, IP telephony devices or servers that communicate with each other and/or with various other network elements or remote servers attached to the network. For example, data networks may comprise, without limitation, Metro Ethernet or Enterprise Ethernet networks that support multiple applications including, for example, voice-over-IP (VoIP), data and video applications. Such networks regularly include interconnected nodes, commonly known as switches or routers, for routing traffic through the network.

One of the key challenges faced by data networks is the need for network resiliency, i.e., the ability to maintain high availability despite eventual component failures, link failures or the like, which is critical to providing satisfactory network performance. Network resiliency may be achieved in part through topological redundancy, i.e., by providing redundant nodes (and redundant components within nodes) and multiple physical paths between nodes to prevent single points of failure, and in part through L2/L3 protocols to exploit the redundancy upon occurrences of failures to converge upon alternate paths for switching/routing traffic flows through the network. As will be appreciated, detection and convergence times must occur quickly (advantageously, in less than one second) in networks to achieve seamless transition to the alternate paths. Various types of network topologies are implemented within a network to provide redundancy between network elements, such as a ring networks, partial mesh networks, full mesh networks, hub networks, etc. Convergence times and redundancy between network elements often varies depending on the type of network typology implemented in a network.

Architectures of network elements also vary and affect network resiliency. For example, various node architectures include single switching elements, stackable switching elements, multi-slot chassis based network elements, etc. In general, depending on cost and network needs, one of these types of node architectures is selected and implemented into one of the types of network topologies. However, once implemented, it is sometimes difficult to upgrade or transition from one type of network topology to another type of network topology. It is also difficult to transition from one type of node architecture to another type of node architecture within a network topology or to incorporate various types of node architectures within one network.

Accordingly, there is a need for systems and methods for providing resiliency between nodes having one or more different types of node architectures in one or more different types of network topologies.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIGS. **1***a-c* illustrate schematic block diagrams of embodiments of a virtual chassis system in accordance with the present invention;

FIG. **2** illustrates a logical flow diagram of an embodiment of a network topology discovery process in a virtual chassis system in accordance with the present invention;

FIG. **3** illustrates a schematic block diagram of an embodiment of topology database in a network node in a virtual chassis system in accordance with the present invention;

FIG. **4** illustrates a schematic block diagram of an embodiment of network nodes in a virtual chassis system in accordance with the present invention;

FIG. **5** illustrates a schematic block diagram of an embodiments of a network interface module of a network node in a virtual chassis system in accordance with the present invention;

FIG. **6** illustrates a schematic block diagram of an embodiment of a pre-pended header of a packet in the virtual chassis system in accordance with the present invention;

FIG. **7** illustrates a schematic block diagram of an embodiment of packet flow through a network node in a virtual chassis system in accordance with the present invention;

FIG. **8** illustrates a schematic block diagram of an embodiment of a virtual chassis manager application in accordance with the present invention;

FIG. **9** illustrates a schematic block diagram of an embodiment of a configuration manager module in accordance with the present invention;

FIG. **10** illustrates a logical flow diagram of an embodiment of a method for determining an operation mode of a network node in a virtual chassis system in accordance with the present invention.

FIG. **11** illustrates a logic flow diagram of an embodiment of a method for configuring a network node at start-up in virtual chassis mode in accordance with the present invention;

FIG. **12** illustrates a schematic block diagram of an embodiment of configuration conversion from standalone to virtual-chassis mode in accordance with the present invention;

FIG. **13** illustrates a schematic block diagram of an embodiment of configuration conversion from virtual-chassis mode to standalone mode in accordance with the present invention;

FIG. **14** illustrates a schematic block diagram of an embodiment of master address retention in a virtual chassis system in accordance with the present invention;

FIG. **15** illustrates a schematic block diagram of an embodiment of master address release in a virtual chassis system in accordance with the present invention;

FIG. **16** illustrates a schematic block diagram of an embodiment of master network node failure in a virtual chassis system in accordance with the present invention;

FIG. **17** illustrates a schematic block diagram of an embodiment of VFL failure in a virtual chassis system in accordance with the present invention;

FIG. **18** illustrates a logic flow diagram of an embodiment of a method for recovery from a failure of a master network node in a virtual chassis system in accordance with the present invention;

FIG. **19** illustrates a schematic block diagram of an embodiment for a remote debugging system in accordance with the present invention;

FIG. **20** illustrates a logic flow diagram of an embodiment of a method for redirection of an output of a remote debug module in accordance with the present invention;

FIG. **21** illustrates a logic flow diagram of an embodiment of a method for remote access of a network node in the virtual chassis system in accordance with the present invention; and

FIG. **22** illustrates a logic flow diagram of an embodiment of a method for a management interface module in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The following standards are referred to in this application and are incorporated by reference herein: 1) the Link Aggregation Control Protocol (LACP) which was formerly clause 43 of the IEEE 802.3 standard added in March 2000 by the IEEE 802.3ad task force and is currently as incorporated in IEEE 802.1AX-2008 on Nov. 3, 2008; and 2) IEEE Std. 802.1Q, Virtual Bridged Local Area Networks, 2003 edition.

FIG. **1***a* illustrates an embodiment of a virtual chassis system **100** including a plurality of network nodes **110** operably coupled by dedicated link aggregate groups for communicating control and addressing information called virtual fabric links (VFLs) **120**. VFLs **120** and their operation are described in more detail in U.S. patent application Ser. No. 13/010,168, entitled, "SYSTEM AND METHOD FOR MULTI-CHASSIS LINK AGGREGATION," filed Jan. 20, 2011, pending, which is incorporated by reference herein and made part of the present U.S. Utility patent application for all purposes. The VFLs **120** provide connections between the network nodes **110** for exchange of information related to traffic forwarding, MAC addressing, multicast flows, address resolution protocol (ARP) tables, Layer 2 control protocols (e.g. spanning tree, Ethernet ring protection, logical link detection protocol), routing protocols (e.g. RIP, OSPF, BGP) and the status of the network nodes and external links.

In an embodiment, the plurality of network nodes **110** operate as a single virtual network node with unified management capabilities. A master network node, e.g. network node **110***a*, is selected and the local MAC address of the master network node **110** is adopted as the master MAC address for the virtual chassis system **100** by the other network nodes **110**. The master MAC address is utilized by external nodes **112** to address the network nodes **110** in the virtual chassis system **100**. As such, the network nodes **110** operate transparently to the external nodes **112** and are treated as a single logical device by the external nodes **112**.

External nodes **112** are operable to couple to one or more network nodes **110** in the virtual chassis system **100** using a single trunk or link, a link aggregate group (LAG) **116** or virtual-chassis link aggregate groups (VC-LAG) **114**. To provide increased resiliency and remove a single point or even two points of failure, VC-LAG **114** is operable to couple an external node to two or more network nodes **110** in the virtual chassis system **100**. The external node can use load balancing techniques to distribute traffic across the available links of VC-LAG **114**. For example, one of the physical links of the VC-LAG **114** is selected by the external node to transmit a packet based on a load-balancing algorithm (usually involving a hash function operating on the source and destination Internet Protocol (IP) or Media Access Control (MAC) address information) for a more effective use of bandwidth.

During normal operation, the network nodes **110** within the virtual-chassis system share the master MAC address for system identification by a wide variety of layer 2 and layer 3 protocols. For example, the spanning tree protocol and LACP protocols use the master MAC address as the identifier for the virtual chassis system **110**. Internet Protocol (IP) routing also utilizes the master MAC address to identify the virtual chassis system **100** to external network elements in the network, e.g. peers use the master MAC address as the Ethernet destination address for packets destined to the virtual chassis system **100**. As such, the network nodes **110** within the virtual chassis system **100** are viewed as a single logical node by external network nodes **112**. In addition, the network nodes **110** within a virtual chassis system **100** are managed as a single node with a unified administration, operations and maintenance management system.

Since the network nodes **110** within a virtual chassis system **100** are treated as a single logical device by external nodes **112**, the external nodes **112** are operable to actively forward traffic on all the links of the VC-LAG **114**. This feature enables multiple homing of the external nodes **112** to the network nodes **110** without requiring spanning tree protocols between the external nodes and network nodes while still facilitating a carrier-grade detection and convergence time to edge uplink failures as well as network node **110** failures. Another advantage of the active forwarding mode of all the VC-LAG **114** uplinks to the virtual chassis system **100** is increased efficiency of the use of bandwidth of the VC-LAG **114** links.

Within the virtual chassis system **100**, a network node **110** is assigned a globally unique identifier called a chassis identifier or chassis ID. The network node **110** assigns an internal VFL identifier (VFID) to each of its configured VFLs **120** within the virtual chassis system **100**. Since the VFID for a VFL is utilized for internal identification and configuration of VFLs **120**, a network node **110** may assign the same or a different VFID to a VFL **120** as assigned by another network node **110**. The VFLs **120** provide a connection for exchange of information between the network nodes **110** regarding traffic forwarding, MAC addressing, multicast flows, address resolution protocol (ARP) tables, Layer 2 control protocols (e.g. spanning tree, Ethernet ring protection, logical link detection protocol), routing protocols (e.g. RIP, OSPF, BGP), as described in more detail in U.S. patent application Ser. No. 13/010,168, entitled, "SYSTEM AND METHOD FOR

MULTI-CHASSIS LINK AGGREGATION," filed Jan. 20, 2011. In an embodiment, synchronization of layer 2 address tables, such as medium access control (MAC) address tables, between the network nodes **110** is driven by layer 2 packet flows over the VFLs **120** as well as by a periodic keep-alive mechanism whereby the network node **110** that owns a given MAC address floods specific packets bearing such MAC address as the source address. The synchronization mechanism also needs to implement the standard MAC flushing mechanism to handle cases where a network node **110** or some of its components go down. MAC address source learning is enabled over the VFLs **120** through flooding of unknown destination MAC addresses. During source learning, the network nodes **110** exchange packets with prepended headers over the VFLs **120** that include source MAC addresses and associated hardware device information, such as source chassis ID, source network interface identifier and source port identifier information. The network nodes **110** use this information to maintain synchronized MAC address tables with minimum messaging based MAC table synchronization. Utilizing the synchronized MAC address table, the network nodes **110** are operable to process and forward packets between the network nodes **110** in the virtual chassis system **100**.

FIG. **1***a* illustrates that the network nodes **110** are coupled in a partial mesh network topology. However, the network nodes **110** in a virtual chassis system **100** may be coupled in any of a plurality of types of network topologies without affecting operation of the virtual chassis system **100**. FIG. **1***b* illustrates a virtual chassis system **100** with a plurality of network nodes **110** configured in a ring network topology coupled by VFLs **120**. FIG. **1***c* illustrates a virtual chassis system **100** with a plurality of network nodes **110** configured in a hub and spoke or star type network topology. Other network topologies not depicted, such as linear, tree, full mesh, hybrid, etc., are also be supported by the virtual chassis system **100**. To support the plurality of different types of network topologies, the network nodes **110** in a virtual chassis system **100** are operable to perform a network topology discovery process.

FIG. **2** illustrates a logical flow diagram of an embodiment of a network topology discovery process **130** in a virtual chassis system **100**. The process is performed by the active network nodes **110** in the virtual chassis system **100** at start-up, reboot, on indication of a status change in the network or at predetermined time periods. In step **132**, a network node **110** detects that it is operating in a virtual chassis mode. For example, one or more parameters of the network node **110** are configured to indicate a virtual chassis mode of operation. The network node **110** detects that the parameters indicate virtual chassis mode operation (e.g., rather than stand-alone mode or multi-chassis mode). The network node **110** then performs in step **134** one or more control protocols to discover other network nodes **110** in the virtual chassis system **100** and to exchange topology and configuration information. The network node **110** uses the information to build a topology database of the virtual chassis system **100**. The topology database includes: identification information for the other network nodes **110** (e.g., local MAC address, chassis identifier), identification information for network interfaces that host active VFLs **120** (or other active inter-switch links), identification information for the VFLs **120** and their associated member ports on the network nodes **110**. The network node **110** thus learns the active connections between the network nodes **110** and configuration information of the other network nodes **110** in the virtual chassis system **100**. The following Table 1 is an example of a topology database for a network node **110***a*, in this example with e.g. chassis ID=1, following the discovery phase. Table 1 includes exemplary information stored in the topology database but other information and data not illustrated may also be included in the topology database. In addition, the topology database may be stored in separate databases or tables or combined with other tables or databases in the network node **110**.

TABLE 1

Topology Database - Chassis 1			
Local Chassis Data	Neighbor [1]	Neighbor [2]	Neighbor [3]
Chassis ID = 1 Uptime = 4 min 50 sec Priority = 100 Chassis MAC = A Chassis Group = 0 Primary CMM = CMM-A Chassis type = OS10K Role = unassigned State = unassigned	Chassis ID = 2 Uptime = 5 min 10 sec Priority = 100 Chassis MAC = B Chassis Group = 0 Primary CMM = CMM-A Chassis type = OS10K Role = unassigned State = unassigned	Chassis ID = 4 Uptime = 5 min 5 sec Priority = 100 Chassis MAC = D Chassis Group = 0 Primary CMM = CMM-B Chassis type = OS10K Role = unassigned State = unassigned	Chassis ID = 3 Uptime = 5 min 1 sec Priority = 100 Chassis MAC = C Chassis Group = 0 Primary CMM = CMM-A Chassis type = OS10K Role = unassigned State = unassigned

In step **136** of FIG. **2**, a master network node is selected to perform management and other tasks for the virtual chassis system **100**. The local MAC address of the master network node is then adopted by the other network nodes **110**. The following Table 2 is an example of a topology database for the elected master network node **110** with chassis ID=1. As seen in Table 2, network node with chassis ID=1 is indicated as having the master role and the other nodes are indicated as having a slave role in the topology database.

TABLE 2

Topology Database - Chassis 1			
Local Chassis Data	Neighbor [1]	Neighbor [2]	Neighbor [3]
Chassis ID = 1 Uptime = 5 min 50 sec	Chassis ID = 2 Uptime = 6 min 10 sec	Chassis ID = 4 Uptime = 6 min 5 sec	Chassis ID = 3 Uptime = 6 min 1 sec

TABLE 2-continued

Topology Database - Chassis 1			
Local Chassis Data	Neighbor [1]	Neighbor [2]	Neighbor [3]
Priority = 100 Chassis MAC = A Chassis Group = 0 Primary CMM = CMM-A Chassis type = OS10K Role = master State = running	Priority = 100 Chassis MAC = B Chassis Group = 0 Primary CMM = CMM-A Chassis type = OS10K Role = slave State = running	Priority = 100 Chassis MAC = D Chassis Group = 0 Primary CMM = CMM-B Chassis type = OS10K Role = slave State = running	Priority = 100 Chassis MAC = C Chassis Group = 0 Primary CMM = CMM-A Chassis type = OS10K Role = slave State = running

The selection of a master network node **110** is based on a prioritized list of parameters including chassis priority, up time, chassis ID and chassis MAC address. The parameter of up time gives priority to network nodes **110** in operation for longer periods of time. The parameter of chassis priority is a user configured priority that defines the user preference of a master network node **110** regardless of chassis ID or up time. The use of various parameters adds flexibility to the selection of a master network node **110**. The chassis group parameter shown in the topology database identifies the virtual chassis system **100**. One or more additional virtual chassis systems **100** with different chassis group identifications may also be operable in a network. The topology database also identifies the active or primary control manager modules (CMM) in a network node **110** and the chassis type of the network node **110**.

In step **138** of the network topology discovery process **130**, the network node **110** performs one or more protocols to monitor the state or status of the connections and the network nodes **110** in the virtual chassis system **100**. The current state of the network nodes **110** is maintained in the topology database. A detected status change in a network node **110** in the virtual chassis system **100** may initiate a change in routing, a change in the master node, etc. Through topology self-discovery and monitoring of the network nodes **110**, the virtual chassis system **100** is operable to support a plurality of different types of network topologies with minimum pre-configuration and intervention.

FIG. **3** illustrates an example of topology databases **144** in network nodes **110** in a virtual chassis system **100** after selection of a master network node **110**. In this example, network node **110***a* is adopted as the master network node and network nodes **110***b* and **110***c* are slave nodes. The local MAC address of network node **110***a* (e.g., master MAC address=A) is adopted by the network nodes **110***a-c* as the virtual chassis MAC address. In addition, the master MAC address (MAC=A) is adopted as the application MAC address for management applications.

The virtual chassis system **100** is also operable to include network nodes **110** with one or more different types of node architectures, such as single module, stackable, or multi-slot chassis-based architectures. FIG. **4** illustrates a schematic block diagram of an embodiment of network nodes **110** in a virtual chassis system **100** with different types of node architectures. In this example, network node **110***a* has a multi-slot chassis-based architecture with a plurality of network interface modules **152***a-n*. In general, multi-slot chassis-based architectures share one enclosure, control manager modules (CMMs) **150***a-b* and a common power supply with one or more network interface modules (NIMs) **152***a-n*, such as line cards or port modules. The network interface modules **152***n* include a queuing module **212** and switching module **210** and are connected by a fabric switch **214** integrated into the backplane of the chassis.

Network node **110***b* in this example has a stackable node architecture and includes a plurality of network elements **140***a-n* coupled by backplane connections **142**. Each network element **140***a-n* is operable as a stand-alone node and includes its own enclosure, control manager module (CMM) **150**, switching module **210**, queuing module **212** and power supply. In some stack architectures, one network element (Network Element **140***a* in this example) is designated as the main or master unit of the stack for management purposes.

Network node **110***c* has a single module node architecture, such as a single stackable element **140** or alternatively, a multi-slot chassis-based architecture with a single network interface module **152**.

Network nodes **110***a-c* correspond to one or more of the network elements **110** in virtual chassis system **100** in FIGS. **1***a-c*. For example, virtual chassis system **100** is operable to include network nodes **110** with only multi-slot chassis-based node architectures or include network nodes **110** with only stackable node architectures or include a combination of network nodes **110** with two or more types of node architectures, such as multi-slot chassis-based architectures, stackable node architectures and single module node architectures. Though not shown, the virtual chassis system **100** may also include network nodes **110** comprised of other types of node architectures and configurations.

Network node **110***a* and network node **110***b* are operably coupled by VFL **120***a*. The network nodes **110***a* and **110***b* designate VFL **120***a* with an internal VFL identifier (VFID), such as VFID=3 for network node **110***a* and VFID=0 by network node **110***b* as shown in FIG. **3**. Network node **110***a* and network node **110***c* are operably coupled by VFL **120***b*. The network nodes **110***a* and **110***c* designate VFL **120***b* with an internal VFL identifier (VFID), such as VFID=2 for network node **110***a* and VFID=1 by network node **110***c* as shown in FIG. **3**. In addition, the network nodes **110***a-c* are also operable to be coupled by additional VFL **120***s* to one or more other network nodes **110** as shown in FIGS. **1***a-c*. The VFL **120***a* between network nodes **110***a* and **110***b* is described below as a generalization of the operation and configuration of the VFLs **120** between the various network nodes **110** in a virtual chassis system **100**.

VFL **120***a* between network node **110***a* and network node **110***b* is operably coupled to one or more VFL member ports in one or more switching modules **210**. For redundancy in case of failure of one or more ports, links or modules, VFL **120***a* is operable to include a plurality of aggregate links generated using the LACP or similar aggregate protocol between different switching modules **210** of the network nodes **110***a* and **110***b*. For example, in FIG. **4**, VFL **120***a* includes a first subset A of physical links between NIM **152***a* of network node **110***a* and stackable network element **140***a* of network node **110***b* and a second subset B of physical links between NIM **152***b* of network node **110***a* and stackable network element **140***b* of network node **110***b*.

The network nodes **110** are assigned a unique chassis identifier in the virtual chassis system **100**. The chassis ID for each network node **110** is unique and global and through the topology discovery, the network nodes **110** are aware of the chassis ID of its peer network nodes **110** in the virtual chassis system **100**. In addition, unique hardware device identifiers or module identifiers (MIDs) for various components, such as the switching modules **210** and port interfaces in the network nodes **110**, are generated allowing for management of local and remote objects. In an embodiment, the hardware device identifiers MIDs for the switching modules **210** have global significance within the virtual chassis system while MIDs for other components, such as queuing modules **212**, may have only local significance. For example, the hardware device identifiers' assigned to the switching modules **210** are known by other network nodes **110** while hardware device identifiers for other devices are restricted to a local network node **110** and have no significance to other network nodes **110**. For example, the port interfaces of a switching module **210** are assigned a global unique hardware device identifier that includes the chassis ID, switching module ID and port interface ID. In an embodiment, the network nodes **110** in the virtual chassis system operate in a pre-pended header mode to exchange data and control packets over the VFLs **120**.

FIG. **5** illustrates a schematic block diagram of an embodiment of a network interface module (NIM) **152** operating in a prepended header mode in more detail. Though a network interface module **152** is illustrated, a stackable network element **140** or single module network element is operable to perform similar functions for operating in a prepended header mode. Switching module **210** includes a plurality of external ports **240** that are connected to external nodes **112** from the virtual chassis system **100**. One or more of the external ports **240** may include member ports for a VC-LAG **114**, LAG **116**, single trunk or other trunk group, fixed link, etc. The external ports **240** may have the same physical interface type, such as copper ports (CAT-5E/CAT-6), multi-mode fiber ports (SX) or single-mode fiber ports (LX). In another embodiment, the external ports **240** may have one or more different physical interface types.

The external ports **240** are assigned external port interface identifiers (Port ID), e.g., device port values, such as gport and dport values, associated with the switching module **210**. In an embodiment, the chassis ID of the network node **110**, the MID of the switching module **210** and the external port interface identifier (Port ID) are used as a global unique identifier of a physical external port interface **240** in a network node **110** in the virtual chassis system **100**. In another embodiment, globally unique module identifiers (MID) are assigned to the switching modules **210** of the network nodes in the virtual chassis system based on the chassis identifiers. For example, switching MIDs **0-31** are assigned to chassis ID=1, switching MIDs **32-63** are assigned to chassis ID=2, etc. In this case, the globally unique switching MIDs and external port identifiers (Port ID) are used as a global unique identifier of a physical external port interface **240** in a network node **110** in the virtual chassis system **100**.

When a packet is received on an external port **240**, switching module **210** transfers the packet to a pre-pended packet header interface (PPHI) **246** that adds a pre-pended header (or otherwise modifies the packet header) to include hardware device information (HDI) associated with the source and/or destination MAC address of the packet. In an embodiment, the pre-pended header may include other information such as packet priority and load balance identifiers. To obtain HDI information associated with the MAC address of the packet, the PPHI performs a look-up process in MAC/HDI forwarding table **250**. The MAC/HDI forwarding table **250** stored in the address table memory **248** includes a list of MAC addresses and associated hardware device information. The hardware device information uniquely identifies a network node **110**, switching module **210** and/or a port interface **240** for routing the packet. The hardware device information includes, for example, chassis ID, MID of a switching module **210** and/or port interface ID of a port **240** associated with the destination MAC address. The MAC/HDI forwarding table **250** may include one or more tables, such as source trunk map, trunk bitmap table, trunk group tables, VLAN mapping table, etc. In an embodiment, the MAC/HDI forwarding table **250** or parts thereof may be located in the queuing module of the NIM **152** or other module as well.

Based on the topology database **144**, a VFL routing configuration table **254** is generated at a network node **110** to determine routing of unicast traffic. The VFL routing configuration table **254** includes a chassis ID and an associated VFL ID (VFID). The VFID associated with the chassis ID identifies a VFL **120** in the virtual chassis system **100** for routing the packet to a network node **110** identified by the destination chassis ID. In another embodiment, when globally unique module identifiers (MID) are assigned to the switching modules **210** of the network nodes **110** in the virtual chassis system **100**, the VFL routing configuration table **254** includes the globally unique MIDs and an associated VFL ID (VFID). In an embodiment, the VFL routing configuration table **254** is generated using a shortest path algorithm, traffic based algorithm or other type of routing algorithm. An example of VFL routing configuration tables **254** for the virtual chassis system **100** shown in FIG. **1***a* is illustrated below in Table 3.

TABLE 3

Destination Chassis ID/MID	Outgoing VFL ID	Destination Chassis ID/MID	Outgoing VFL ID
VFL Routing Configuration on Chassis 1		VFL Routing Configuration on Chassis 2	
1 (MID = 0-31)	N/A (local)	1 (MID = 0-31)	0
2 (MID = 32-63)	3	2 (MID = 32-63)	N/A (local)
3 (MID = 64)	2	3 (MID = 64)	3
4 (MID = 65-97)	2 or 1	4 (MID = 65-97)	3 or 1
5 (MID = 98)	1	5 (MID = 98)	1
6 (MID = 99-115)	0	6 (MID = 99-115)	0 or 1
VFL Routing Configuration on Chassis 3		VFL Routing Configuration on Chassis 4	
1 (MID = 0-31)	1	1 (MID = 0-31)	0 or 1
2 (MID = 32-63)	0	2 (MID = 32-63)	0 or 1
3 (MID = 64)	N/A (local)	3 (MID = 64)	1
4 (MID = 65-97)	3	4 (MID = 65-97)	N/A (local)
5 (MID = 98)	3 or 2	5 (MID = 98)	0
6 (MID = 99-115)	2	6 (MID = 99-115)	0 or 1
VFL Routing Configuration on Chassis 5		VFL Routing Configuration on Chassis 6	
1 (MID = 0-31)	2	1 (MID = 0-31)	0
2 (MID = 32-63)	1	2 (MID = 32-63)	0 or 1
3 (MID = 64)	1 or 0	3 (MID = 64)	1
4 (MID = 65-97)	0	4 (MID = 65-97)	1 or 2
5 (MID = 98)	N/A (local)	5 (MID = 98)	2
6 (MID = 99-115)	1	6 (MID = 99-115)	N/A (local)

Though the MAC/HDI forwarding table **250** and VFL routing table **254** are illustrated as separate tables in address table memory **248**, the tables may be combined or data included from one of the tables into the other table or the tables may be separated into one or more other tables.

In an embodiment, the hardware device information HDI in the pre-pended header of a packet includes the outgoing VFID for the VFL port **252** associated with the destination chassis ID, as shown in Table 3. The pre-pended header also includes hardware device information HDI associated with the source port receiving the packet, such as the port interface ID, MID of the switching module **210** and chassis ID. Additional information, such as VLAN ID, packet type (multicast, unicast, broadcast), packet priority and load balance identifier is also added to the pre-pended header in an embodiment.

The packet with the pre-pended header is then transmitted to the queuing module **212** for routing over the fabric switch **214**. Based on the VFL routing configuration table **254**, the queuing module **212** routes the packet with the pre-pended header to the switching module **210** connected to the outgoing VFL **120**.

The queuing module **212** includes a packet buffer **260**, a queue management **262** for providing traffic and buffer management and a global HDI address table **264**. The global HDI address table **264** maps the outgoing VFL ID to the appropriate queues in queuing modules **212** in one or more of the other NIMs **152**. For example, the queuing module **212** switches the packet to an appropriate egress queue for one or more of the VFL port interfaces **252** for transmission over the outgoing VFL **120**. In an embodiment, a determination of the egress queue corresponding to a particular VFL port interface is operably based on a load balance identifier in the pre-pended header.

Though the switching module **210** and queuing module **212** are illustrated as separate integrated circuits or modules, one or more functions or components of the modules may be included on the other module or combined into an alternate module or otherwise be implemented in one or more integrated circuits.

FIG. **6** illustrates a schematic block diagram of an embodiment of a pre-pended header of a packet in the virtual chassis system **100**. The pre-pended header **300** includes fields for source HDI **302**, destination HDI **304**, VLAN ID **306**, packet type **308**, source MAC address **310** and destination MAC address **312**. In an embodiment, the pre-pended header may also include, load balance identifier **314** and packet priority **316**. The destination HDI **304** includes, for example, the port identifier (either device port (dport) and/or global port value (GPV)), MID of switching module **210** and chassis ID of the destination network node **110** associated with the destination MAC address. The source HDI **302** includes, for example, the port identifier (either device port (dport) and/or global port value (GPV)), MID of switching module **210** and/or chassis ID of the source network node associated with the source MAC address. The load balance identifier **314** is utilized by the queuing module **212** to determine a VFL member port for transmission of the packet over the outgoing VFL **120**. The packet priority **316** is utilized by the queuing module **212** to determine the specific priority queue.

FIG. **7** illustrates a schematic block diagram of an embodiment of a packet flow through a network node **110***a* to another network node **110***b* in a virtual chassis system **100**. In this example, an external device **300** from the virtual chassis system **100** with source MAC address "MAC1" transmits a packet with a destination MAC address "MAC2". Network node **110***a*, with Chassis ID=1 in this example, receives the packet at external port interface **240**, e.g. with port ID=2 on switching module **210***n*, e.g. with MID=31. The switching module **210***n* extracts the destination MAC address MAC**2** and performs an address table look-up in MAC/HDI forwarding table **250** to determine hardware device information (HDI) associated with the destination MAC address MAC**2**. The destination HDI may include, e.g., destination chassis ID and device module identifier (MIDs) and port identifiers associated with the destination MAC address. The destination HDI may also include identifiers of one or more other network nodes or hardware modules in a path to the destination device associated with the destination MAC address. When the destination MAC address is associated with another network node, e.g. destination chassis ID is not the local chassis ID, the switching module **210** determines an outgoing VFL ID associated with the destination chassis ID. The outgoing VFL ID may be added to the destination HDI in the pre-pended header. For the example in FIG. **5**, the VFL routing table **254** indicates that the destination chassis ID=2 is associated with VFL **120** having VFID=3.

The switching module **210***n* also includes in the prepended header source hardware device information (HDI) associated with the originating external port interface, e.g. port ID=2. The source HDI may include one or more hardware device identifiers, such as MID of the originating switching module **210**, source port identifier, MID for source NIM **152**, source chassis ID, etc. Furthermore, in an embodiment, the pre-pended header includes a packet priority and a load balance identifier determined based on parameters retrieved from the original packet (source MAC address, destination MAC address, source IP address, destination IP address).

The packet with pre-pended header is transmitted to the queuing module **212***n* which then determines a NIM **152** on the network node **110** to transmit the packet based on the destination HDI. When the destination HDI indicates a local external port interface on the network node (e.g. based on the destination MID contained in the pre-pended header), the queuing module places the packet in an egress queue for transmission to the corresponding NIM **152** of the local external port interface. In another example illustrated in FIG. **5**, when the destination HDI indicates that the packet needs to be transmitted over a VFL **120** to another network node **110** in the virtual chassis system **100**, the queuing module determines from the VFL ID the outgoing NIM **152** to transmit the packet. In this example, the queuing module determines that VFID=3 is operably coupled to NIM **152***a* and transmits the packet with pre-pended header over the fabric switch **214** to NIM **152***a*. When multiple switching modules **210** are operably coupled to the outgoing VFL **120**, the traffic to be transmitted may be distributed between the multiple switching modules **210** in a load balancing method. In addition, the selection of a VFL member port (high priority queue, low priority, etc.) on a switching module **210** is operably based on load balance identifier parameters carried on the pre-pended header. The queuing module **212***a* on NIM **152***a* receives the packet with pre-pended header and queues the packet for transmission over VFL **120** with VFID=3. The switching module **210***a* then transmits the packet with pre-pended header including the source and/or destination HDI to the network node **110***b*, chassis ID=2 over the VFL **120** with VFID=3.

In an embodiment, the switching module **210***a* may alter the pre-pended header prior to transmission over the VFL **120**. For example, the switching module **210***a* may translate a destination HDI with local significance (e.g., a gport value or local hardware device identifier MID) to an HDI with global significance or remove the outgoing VFID from the pre-pended header.

In an embodiment, the MAC/HDI forwarding tables **250** in the NIMs **152** are populated and updated in response to layer 2 packet flows through the virtual chassis system **100**. Since the pre-pended header includes source MAC address and source HDI information, the NIMS **152**, e.g. in specific the switching modules **210** in an embodiment, are able to populate the MAC/HDI forwarding table **250** with this information. By operating in a pre-pended header mode to exchange Layer 2 packets with source MAC addresses and source HDI over the VFL **120**, the switching modules **210** are able to synchronize the MAC/HDI forwarding tables **250** between the network modules **110** in a virtual chassis system **100**. Though the MAC/HDI forwarding table **250** and VFL routing table **254** are described as located in the switching modules **210**, the tables may be included, alternatively or in addition to, in the queuing modules **212***n* or other module of the network node **110**. In another embodiment, the CMM **150** (primary and secondary) may also include the MAC/HDI forwarding table **250** and VFL routing table **254**.

FIG. **8** illustrates a schematic block diagram of an embodiment of a virtual chassis manager application or module **400** operable in the network nodes **110** in the virtual chassis system **100**. In an embodiment of a network node **110** with a multi-slot chassis based node architecture, the virtual chassis manager module **400** includes a distribution of functionality between the central management module (CMM) **150** of the network node **110** (called VCM-CMM **402**) and a processing module **266** in a designated network interface module (NIM) **152** of the network node (called VCM-NIM **404**). In a stackable node architecture, a designated or master stackable network element **140** operates the VCM-NIM **404**. Use of a designated NIM **152** or stackable element **140** avoids centralizing the functions of the VCM module **400** only at a CMM **150**. An example of a distribution of functionality of the virtual chassis manager module **400** is shown in Table 4.

TABLE 4

VCM-CMM 402	VCM-NIM 404
Element and network management interface to the virtual chassis functionality Coordination of the virtual chassis operation and states from a network node overview	Control protocol state machines Service interfaces with other software components, i.e. interfaces used by the VCM module 400 to provide or request services to/from other software components. Programming of the underlying switching module devices: global module identifiers (MID), loop prevention, virtual chassis inter-process communication infrastructure, VFL member port programming, etc.

In an embodiment, the VCM-CMM **402** includes an interface between the virtual chassis manager module **400** and element and/or network manager module **406** as well as an interface to other applications **408** registered with VCM module **400** operable on the network node **110**. The virtual chassis manager module **400** informs the registered applications **408** when to operate in the virtual chassis mode. More generally, the virtual chassis manager module **400** provides a wide range of notifications to inform interested applications about the status of the virtual chassis system both in the context of the local node and other network nodes **110** in the virtual chassis system **100**. Some of the status information is driven by management configuration, whereas other status information is triggered by runtime decisions taken by the network node individually or by a plurality of the network nodes **110** within the virtual chassis system upon control data exchange, negotiation and agreement. The virtual chassis manager module **400** also interfaces with the VLAN Manager Application module **410**, Spanning Tree Protocol (STP) application module **412**, Source Learning application module **414**, Link Aggregation application module **416** and Port Manager application module **418** for the purposes of requesting services from these system components. For example, the VCM **400** may request VLAN Manager to configure a VFL member port as a member of the control VLAN in order to allow the set-up of an inter-process communication channel between the network nodes **110** in the virtual chassis system **100**.

The VCM-NIM **404** performs module identification configuration (e.g. MID) of hardware modules. The VCM-NIM **404** also interfaces with the queue management **262** in queuing modules **212** to perform hardware device/queue mapping functions and inter-chassis loop avoidance functions. The VCM-NIM **404** also includes virtual chassis state functionality for the control and management of the VFLs **120**. Virtual Fabric Link Control manages and configures the VFLs **120** and interfaces with the port manager application module **418** to monitor and/or control the state of the VFLs **120** and their corresponding member ports. It also tracks and updates the status of the VFLs **120**. The VCM-NIM **404** tracks the state of each VFL member port using the standard LACP protocol, or other similar protocol, along with the state of the link at the physical level. In addition to the LACP protocol, a virtual chassis status protocol performs periodic keep-alive checks (hello protocol) in order to check the status and/or operability of components running on the designated NIM on both virtual-chassis switches. All virtual chassis protocol packets must be assigned a high priority in the system to avoid false/premature failure detection because such a premature detection of failure may have a very disruptive effect in the system. By running the virtual chassis status protocol on a primary designated NIM **152**, the back-up designated NIM module is able to assume control of the status protocol processing in the event of failure.

The VCM-CMM **402** and the VCM-NIM **404** register with port manager application module **418** to receive port state and link state events about the member ports and links of the VFLs **120**. In another embodiment, the virtual chassis manager module **400** may include a port manager application module to monitor the port and link state of the VFLs **120**. The virtual chassis manager module **400** tracks the operational state of VFLs **120** and processes events about the VFL status, i.e. aggregate created/deleted/up/down. The port manager application module **418** provides link state notifications to both the VCM-CMM **402** and VCM-NIM **404**.

In an embodiment, a transport control protocol is implemented in a virtual chassis system **100** to transport control protocol packets between designated NIMs **152** or stackable network elements **140** of network nodes **110**. The transport control protocol is operable in the network nodes **110** with different node architectures. For a multi-slot chassis based node architecture, a designated NIM **152** with a designated processing module **266** operates the transport control protocol, e.g. as part of the VCM-NIM **404**. In a stackable node architecture, a designated or master stackable network element **140** operates the transport control protocol.

Chassis supervisor module **420** provides an interface to hardware of the network node **110** and controls monitoring and boot-up or restart of the various application modules, controls software reloads and software upgrades (such as in-service software upgrades ISSUs), providing a command line interface (CLI) for the element manager module **406** and controls access to status or image files of system of the network node **110**. During virtual chassis mode, the chassis supervisor module **420** controls boot sequence, controls software reloads and ISSUs and provides an interface for accessing virtual chassis parameters.

Configuration manager module **422** is operable to convert operation of the network node **110** from a virtual chassis mode to a standalone mode or convert a network node **110** from a standalone mode to a virtual chassis mode. Configuration manager module is also operable to configure the virtual chassis manager module **400** and multi-chassis manager module **424**. The operation of the configuration manager module **422** and operation states of a network node **110** are described in more detail below.

The network nodes **110** in a virtual chassis system **100** may operate in a plurality of operation modes, including virtual chassis mode, standalone mode and multi-chassis (MC-LAG) mode. Various parameters and configurations are modified depending on the operation mode. Table 5 illustrates the assignment of chassis IDs to network nodes **110** depending on the mode of operation.

TABLE 5

Operation Mode	Minimum Chassis ID	Maximum Chassis ID
Standalone	0	0
Multi-Chassis (MCLAG)	1	2
Virtual-Chassis	1	N

In standalone mode, a network node **110** is operated as a single node and utilizes its configured local MAC address rather than a global Virtual Chassis MAC address. In multi-chassis mode, two network nodes are configured as virtual nodes whose MAC forwarding tables and ARP tables are synchronized, but they still operate as separate bridges and routers, each of them using their own local chassis MAC address, as described in more detail in U.S. patent application Ser. No. 13/010,168, entitled, "SYSTEM AND METHOD FOR MULTI-CHASSIS LINK AGGREGATION," filed Jan. 20, 2011. In virtual chassis mode as described herein, a plurality N of network nodes are configured as virtual chassis nodes in a virtual chassis system **100**. A globally unique chassis ID from 1 to N is assigned to each of the plurality of network nodes in the virtual chassis system **100**.

When a network node **110** operates in standalone mode, port identifiers and configurations follow a format: 0/<slot>/<port>, where the chassis ID equals "zero", slot identifies each Network Interface Module (NIM) **152** in a multi-slot architecture or stackable network element **140** and port is the port interface identifier. When a network node **110** operates in multi-chassis mode, port configurations follow a format: <chassis>/<slot>/<port>, where the chassis ID equals 1 or 2 and represents the operation/current/running chassis ID. When a network node **110** operates in virtual chassis mode, port configurations follow a format: <chassis>/<slot>/<port>, where the chassis ID is a number in the range 1, 2 . . . N and represents the operation/current/running chassis ID.

FIG. **9** illustrates a schematic block diagram of configuration manager module **422** in more detail. Configuration manager module **422** includes various configuration modules to support the different modes of operation of a network node **110**. Boot configuration module **440** in an embodiment supports standalone and multi-chassis modes of operation. Virtual Chassis (VC) Mode configuration module **450** supports virtual chassis mode. The configuration manager module **422** reads and validates the relevant configuration files (boot configuration module **440** or VC mode configuration module **450**) at start up and runtime depending on the mode of operation of the network node.

The boot configuration module **440** includes a set of management commands that define resources and specify the network node's parameters and functions in standalone or multi-chassis mode. The boot configuration module **440** includes the application configuration module **442** and the VC Manager configuration module **446***a*. The application configuration module **442** is used to control configuration of various applications in the network node **110**. For example, the application configuration module **442** configures chassis supervisor module **420**, VLAN manager application module **410**, STP application module **412**, multi-chassis manager **424**, etc. The VC Manager configuration module **446***a* includes configuration parameters and control commands processed by the virtual chassis manager **400**. The VC manager configuration module **446***a* is updated and utilized in the boot configuration module **440** when operating in standalone mode. Commands that are specific to the local network node and required to transition the network node to a virtual chassis mode are included in the VC manager configuration module **446***a*.

However, when operating in virtual chassis mode, the VC manager configuration module **446***b* in VC mode configuration module **450** is updated and utilized. By including the VC manager configuration modules **446***a* and **446***b* in the boot configuration module **440** and VC mode configuration module **450**, the network node **110** is operable to perform virtual-chassis related configurations and functions while operating in multi-chassis mode or standalone mode or virtual chassis mode.

VC mode configuration module **450** includes a set of management commands that define resources and specify the network node's parameters and functions in virtual chassis mode. The VC Boot configuration module **452** includes the virtual chassis configurations **458***a-n* of the plurality of network nodes in the virtual chassis system **100** while the VC setup module **460** includes the local chassis configurations.

FIG. **10** illustrates a logical flow diagram of an embodiment of a method **470** for determining an operation mode of a network node **100** in a virtual chassis system **100**. Chassis supervisor module **420** needs to determine the operation mode (e.g., virtual chassis, standalone or multi-chassis) of the network node **110** at start up prior to configuration because the operation mode determines whether the chassis supervisor module **420** will initiate the multi-chassis manager **424** or the virtual chassis manager **400**. In step **472**, the network node starts up and in step **474**, chassis supervisor module **420** determines whether the VC setup module **460** (vcsetup.cfg) is present in the network node **110**. When the VC setup module **460** (vcsetup.cfg) is not present, the network node is not operating in virtual chassis mode, and configuration manager module **422** parses the Boot Configuration Module **440** (boot.cfg file) in step **476** for operation in standalone or multi-chassis mode. The multi-chassis manager **424** is then initiated for processing of the Boot Configuration Module **440** (boot.cfg file) in step **4781**.

When the VC setup module **460** (vcsetup.cfg) is present in step **474**, the network node operates in virtual chassis mode, and chassis supervisor module **420** initiates virtual chassis manager **400**. The chassis supervisor module **420** sets a parameter called "virtual chassis mode" in a shared memory file used by other applications during the start-up process in step **480** to indicate virtual chassis mode operation. The configuration manager module **422** then parses the virtual chassis configuration modules, VC setup module **460** (vcsetup.cfg) and VC boot configuration module (vcboot.cfg), and initiates the virtual chassis manager **400** in step **482**. In step **484**, the virtual chassis manager **400** confirms that the VC setup module **460** (vcsetup.cfg) includes valid virtual-chassis configurations (e.g, a valid chassis ID). Otherwise, the virtual chassis manager **400** informs the chassis supervisor module **420** that the virtual chassis mode has failed. The chassis supervisor module **422** then disables the port interfaces and VFL member ports. As such, a network node **110** that has a VC setup module **460** (vcsetup.cfg) file but its contents are invalid (e.g. out of range chassis ID, corrupted file, manually edited), will not become operational. No attempt is made to operate the network node **110** in standalone mode because, in some scenarios, this may create network problems due to conflicts between the standalone configuration and the virtual chassis configuration of another network node **110** in the virtual chassis system **100**.

FIG. **11** illustrates a logic flow diagram of an embodiment of a method **500** for configuring a network node **110** at startup in virtual chassis mode. At system start up, when the network node **110** is determined to be operating in virtual-chassis mode in step **502** with valid configurations, the virtual chassis manager **400** processes configuration commands in the VC Setup Module **460** to transition the network node **110** into the virtual chassis system **100**. In this initial phase, the virtual chassis manager **400** however does not process the VC boot configuration module **452** commands until a master network node **110** is known and topology database **144** is built by the network node **100**. Table 6 below illustrates configuration of the network node **110** in this initial phase. Note that although Table 6 depicts only two network nodes, any number of network nodes is supported. The Runtime Configuration parameter in Table 6 illustrates the modules or set of commands processed by the network nodes **110** during this initial phase.

TABLE 6

Chassis ID = 1	Chassis ID = 2
vcsetup1.cfg	vcsetup2.cfg
vcboot1.cfg	vcboot2.cfg
Runtime Configuration	Runtime Configuration
vcsetup1.cfg	vcsetup2.cfg

After a master network node is elected and topology database is built in step **506**, the second phase of configuration processing occurs. During the second phase, the master network node **110** in the virtual chassis system **100** performs a merge of the VC boot configuration module **452** in the master network node (e.g., vcboot1.cfg) and the slave network nodes (e.g., vcboot2.cfg) in step **508**. When a network node fails to have the same set of designated configurations in its VC boot configuration module **452**, then the slave network node retrieves the configurations from the master network node and overwrites its own files. The slave network node may then need to reboot so that the new set of parameters takes effect. When the designated configurations of the VC boot configuration module **452** are copied, the copied VC boot configuration module **452** (e.g., vcboot1.cfg) is then processed by the slave network nodes in step **510**. Table 7 illustrates the configuration of the network nodes during the second phase.

TABLE 7

Chassis ID = 1 (Master)	Chassis ID = 2 (Slave)
vcsetup1.cfg	vcsetup2.cfg
vcboot1.cfg	vcboot1.cfg
Runtime Configuration	Runtime Configuration
vcsetup1.cfg + vcboot1.cfg	vcsetup2.cfg + vcboot1.cfg

The VC boot configuration module **452** of the master network node (vcboot1.cfg) has now been copied to the slave network node **2**. To preserve the configurations from the slave network node, the master network node parses the configuration commands in the slave network node's VC boot configuration module (vcboot2.cfg). The parsing may be performed offline or by an element manager or network manager. The conflicting commands in the slave's VC boot configuration module (vcboot2.cfg) are determined and are saved for analysis. The master network node eliminates the conflicting commands and writes the non-conflicting commands into a merged VC boot configuration module **452** (vcboot2'.cfg) for the slave network nodes in step **512**.

In a final stage, the merged VC boot configuration module **452** (vcboot2'.cfg) is copied to the slave network nodes in the virtual chassis system. The VC boot configuration module **452** is then executed by the network nodes **110** in step **514**. Table 8 illustrates the configuration of the network nodes **110** after this final phase.

TABLE 8

Chassis ID = 1 (Master)	Chassis ID = 2
vcsetup1.cfg	vcsetup2.cfg
vcboot1.cfg	vcboot2.cfg
Runtime Configuration	Runtime Configuration
vcsetup1.cfg + vcboot1.cfg + vcboot2'.cfg	vcsetup2.cfg + vcboot1.cfg + vcboot2'.cfg

As a result, the configuration of the slave network nodes **110** are utilized except for conflicting commands without a need to reboot each slave network node **110**. In addition, the configuration of the slave network nodes **110** is preserved.

FIG. **12** illustrates a schematic block diagram of an embodiment of configuration conversion from standalone to virtual-chassis mode. The configuration parameters of a network node **110** need to be converted when transitioning from standalone mode to virtual chassis mode. For example, parameter conversion from standalone to virtual-chassis mode requires modifying port configuration formats from 0/<slot>/<port> to <chassis>/<slot>/<port>. To transition a network node **110** in standalone mode, the network node **110** is configured with certain virtual chassis parameters in VC Setup Module **460** (vcsetup.cfg). For example, element manager module **406** transmits commands (such as through a command line interface) to configure the network node with the virtual chassis parameters. These virtual chassis parameters include, e.g., chassis ID, chassis group, chassis priority, VFL link creation and configuration. Element manager module **406** then enters a convert configuration command that initiates conversion of configurations by the configuration manager module **422**. The configuration manager module **422** converts parameters from the Boot Configuration Module **440** to the VC Boot Configuration Module **452** and VC Setup Module **460** as shown in FIG. **12**. The Boot Configuration Module **440** may need to be resaved or renamed (e.g., Saved Boot Configuration Module **462**) when the module is currently running in standalone mode.

FIG. **13** illustrates a schematic block diagram of an embodiment of configuration conversion from virtual-chassis mode to standalone mode. The configuration of a network node **110** needs to be converted when transitioning from standalone mode to virtual chassis mode. For example, configuration conversion from standalone mode to virtual chassis mode requires modifying port configuration formats from <chassis>/<slot>/<port> to 0/<slot>/<port>. Element manager module **406** enters a convert configuration command that initiates conversion of configurations by the configuration manager module **422** to standalone mode. The configuration manager module **422** converts parameters from the VC Boot Configuration Module **452** and VC Setup Module **460** to the

Boot Configuration Module **440** as shown in FIG. **13**. The VC Boot Configuration Module **452** and VC Setup Module **460** may need to be resaved or renamed (e.g., Saved VC Boot Configuration Module **464** and Saved VC Setup Module **468**) when the modules are currently running in standalone mode.

In a virtual chassis system **100**, when failures are detected in the master network node **110**, its status may be changed from an active to an inactive state. Such failures include, e.g. a power-off, inability to communicate by the CMM or other modules of the master network node or failure of VFL **120** links coupled to the master network node. Upon occurrence of a failure, the remaining active network nodes elect a new master network node. In an embodiment, the remaining active network nodes retain the master MAC address of the failed master network node. In another embodiment, the remaining active network nodes adopt the local MAC address of the newly elected master network node as the new Virtual Chassis MAC address of the virtual chassis system **100**.

FIG. **14** illustrates a schematic block diagram of an embodiment of master address retention in a virtual chassis system **100**. Due to a malfunction or schedule power down maintenance or an inoperable VFL **120** link or other failure, master network node **110***a* is not able to communicate with the remaining nodes **110***b*, **110***c* in the virtual chassis system **100**. The remaining network nodes **110***b* and **110***c* elect a new master network node, in this example, network node **110***b*. In this embodiment, the remaining network nodes **110***b* and **110***c* retain the MAC address of the prior master network node **110***a* as the virtual chassis MAC address for the virtual chassis system **100**. However, the prior master network node **110***a* is removed from the topology database **144** and MAC matrix of the remaining active network nodes **110***b* and **110***c*. This embodiment is termed master MAC retention due to the retention of the prior master MAC address as the virtual chassis MAC address by the remaining active network nodes **110**.

FIG. **15** illustrates a schematic block diagram of an embodiment of master address release in a virtual chassis system **100**. Due to a malfunction or schedule power down maintenance or an inoperable VFL **120** link or other failure, master network node **110***a* is not able to communicate with the remaining nodes in the virtual chassis system **100**. The remaining network nodes **110***b* and **110***c* elect a new master network node, in this example, network node **110***b*. In this embodiment, the remaining network nodes **110***b* and **110***c* release the MAC address of the prior master network node **110***b* as the virtual chassis MAC address. The remaining active network nodes **110***b* and **110***c* adopt the local MAC address of the newly elected master network node **110***b* as the virtual chassis MAC address for the virtual chassis system **100**. The prior master network node **110***a* is removed from the topology database and MAC matrix of the remaining active network nodes **110***b* and **110***c*. This embodiment is termed master MAC release due to the release of the inactive prior master MAC address as the virtual chassis MAC address.

The remaining network nodes **110** determine to retain or release the MAC address of the inactive master network element based on one or more factors. For example, one factor is whether the MAC retention function is administratively enabled. Another factor is whether the change in status of the master network node causes a split in the virtual-chassis system, e.g. the master network node and/or one or more other nodes are still operating using the MAC address of the failed prior master network node. A monitoring protocol or other type of control protocol is used to determine the topology before and after the failure of the master network node to determine whether a split in the virtual chassis system has occurred. When a split in the virtual chassis system has occurred, e.g., the newly elected master network node determines that the prior master network node is still operating, it releases the prior master MAC address as the virtual chassis MAC address. The newly elected master network node may also transition the user ports to a blocking state to prevent duplicative operation of two MAC addresses as the virtual chassis MAC address.

FIG. **16** illustrates a schematic block diagram of an embodiment of master network node failure in a virtual chassis system **100**. In this example, the master network node **110***a* fails and is inoperable. The newly elected master network node **110***b* attempts to determine the status of the prior master network node **110***a* by performing one or more protocols (Hello protocol, ping, etc.) or may request a status update of the network node **110***a* from element manager module **406**. The newly elected master network node **110***b* attempts to distinguish between a failure of the VFL link **120***a* or a failure of the prior master network node **110***a*. When newly elected master network node **110***b* determines that a failure of the prior master network node **110***a* has occurred, e.g. it is no longer operable, the newly elected master network node **110***b* retains the MAC address of the prior master network node **110***a* as the virtual chassis MAC address as shown in FIG. **14**. When the prior master network node **110***a* is removed from the active topology database **144** and the newly elected master network node **110***b* retains the prior master's MAC address, chassis supervisor module **420** starts a MAC retention timer. The MAC retention timer is configurable and sets a predetermined time period for the prior master network node **110***a* to reset and become active. Upon expiration of the predetermined time period, a warning message is generated by the newly elected master network node **110***b* if the prior master network node **110***a* is still inoperable. The virtual chassis system manager may determine to issue a user command to release the retained MAC address and adopt the local MAC address of the newly elected master network node **110***b* as the virtual chassis MAC address for the virtual chassis system **100**.

FIG. **17** illustrates a schematic block diagram of an embodiment of VFL failure in a virtual chassis system **100**. In this example, the VFL **120***a* coupled to the master network node **110***a* fails while prior master network node **110***a* remains operable. The newly elected master network node **110***b* attempts to determine the status of the prior master network node **110***a* by performing one or more protocols (Hello protocol, ping, etc.) or may request a status update of the network node **110***a* from element manager module **406**. The newly elected master network node **110***b* attempts to distinguish between a failure of the VFL link **120***a* or a failure of the prior master network node **110***a*. When newly elected master network node **110***b* determines that a failure of the VFL **120***a* has occurred but that the prior master network node **110***a* is operable, the newly elected master network node **110***b* releases the MAC address of the prior master network node **110***a* as shown in FIG. **15**. The remaining active network nodes **110***b* and **110***c* adopt the local MAC address of the newly elected master network node **110***b* as the virtual chassis MAC address for the virtual chassis system **100**. In addition, the newly elected master network node **110***b* transitions user ports to a blocking state to prevent duplicative operation of two MAC addresses as the virtual chassis MAC address. The release of the MAC address of the prior master network node **110***a* also affects other layer 2 and layer 3 services. For example, spanning tree protocol and LACP may need to reconfigure and/or restart while layer 3 packets may need to be transmitted to neighboring nodes in response to the MAC address change.

FIG. **18** illustrates a logic flow diagram of an embodiment of a method **600** for recovery from a failure of a master network node in a virtual chassis system **100**. In step **602**, due to a malfunction or schedule power down maintenance or an inoperable VFL **120** link or other failure, communication loss is detected with the master network node in the virtual chassis system **100**. The remaining network nodes in the virtual chassis system elect a new master network node in step **604**. In step **606**, the newly elected master network node determines whether a MAC retention function is enabled. If so, in step **608**, the newly elected master network node determines whether the failure causes a split in the virtual-chassis system, e.g. the master network node is inoperable or still operating using its master MAC address. When the master network node is determined to be inoperable, the remaining network nodes retain the MAC address of the prior master network node **110***a* as the virtual chassis MAC address for the virtual chassis system **100** in step **610**. In step **612**, a MAC retention timer begins to time a predetermined time period. Upon expiration of the predetermined time period in step **614**, a warning message is generated by the newly elected master network node if the prior master network node **110***a* is still inoperable.

When the newly elected master network node determines that the prior master network node is still operating in step **608** or that a MAC retention function is disabled in step **606**, it releases the MAC address of the prior master network node as the virtual chassis MAC address in step **616**. The remaining active network nodes adopt the local MAC address of the newly elected master network node as the virtual chassis MAC address for the virtual chassis system **100** in step **618**.

FIG. **19** illustrates a schematic block diagram of an embodiment for a remote debugging system **700**. The remote debugging system **700** is operable to access application modules **720** on remote network nodes **110***b* from a local network node **110***a* in a virtual chassis system **100**. Though described with respect to a multi-slot chassis based node architecture in a virtual chassis system **100**, the remote debugging system **700** is operable in other types of network configurations and node architectures.

The remote debugging module **702** includes a redirection module **704**, remote access module **706** and management interface module **708**. The remote debugging module **702** may be implemented on element manager module **406** or on any other processing module or computing device operably coupled locally or remotely to network node **110***a* in the virtual chassis system **100**. The remote debugging module **702** is operable to communicate with the network node **110***a* using various types of communication protocols, such as telnet session, ssh session, etc. In an embodiment the remote debugging module **702** communicates a debug management command **710** to a control manager module (CMM) **150** in a local network node **110***a*.

In an embodiment, debug management command **710** is received by chassis supervisor module **420** of the CMM **150** of network node **110***a*, though other management modules or applications may process the debug management command **710** in addition to or alternatively from the chassis supervisor module **420** of the CMM **150**. The chassis supervisor module **420** processes the debug management command **710** and generates a process identification (ID) and debug command **712** for execution by the remote network node **110***b*. The process ID or thread identifies a process of an application module **720** for debugging by the debug command. Debug program module **714** receives the process ID and debug command and initiates debug script module **716** in the remote network node **110***b*. The debug script module **716** is a script that preferably initiates batch execution of a number of commands in the identified process in application module **720**. This batch execution is called debug function **722**. The redirect object **724** redirects the output of the debug function **722** to a preselected destination. The remote access module **706** is operable to execute a command to retrieve the output from the preselected destination for storage on the local network node **110***a* in storage module **728** in output file **726**. The output file **726** may then be accessed and reviewed by the remote debugging module **702**.

FIG. **20** illustrates a logic flow diagram of an embodiment of a method for redirection of an output of a remote debug module **702**. The redirection module **704** is operable to redirect an output of a process after execution of the debug function **722**. The output is redirected to a selected location or device, such as a file in a file directory of a virtual terminal (e.g. telnet, ssh), locally connected terminal or remote terminal. In step **752**, a destination of the output of the process is selected and a redirection object **724** is saved with the selected destination. In step **754**, the standard output file descriptor, such as a file and file directory, of the process is stored. In step **756**, after execution of the debug function **722**, the redirection object **724** redirects the output of the process to the selected destination. In step **758**, the redirection object **724** is deleted and the standard output file descriptor is restored.

FIG. **21** illustrates a logic flow diagram of an embodiment of a method **760** for remote access of a network node **110** in the virtual chassis system **100**. The remote access module **706** is operable to provide access for management functions to a remote network node. For example, the remote access module **706** is operable to access a network interface module **152**, a CMM **150**, application module, etc. located on a remote network node through a local network node in the virtual chassis system **100**. Though in an embodiment described herein, debug functions are used as an example, other management functions, such as management commands for operation or configuration, status checks, etc. may also utilize the remote access module **706**. In step **762**, the remote access module **706** establishes a remote session with the target network node or module thereof. The remote access module **706** may include in an embodiment an ssh client application for logging into the remote network node and executing commands though other applications and protocols, such as rlogin, and rsh, mobile shell (MOSH) or other remote access applications may also be implemented. The remote access module **706** opens the remote session with the target network node or module thereof and allows for the execution of the debug function **722** in step **764**. The output of the debug function is stored in the selected directory in step **766** as described with respect to FIG. **20**. The remote access module **706** executes a command to retrieve the stored file from the selected destination in step **768**.

FIG. **22** illustrates a logic flow diagram of an embodiment of a method **770** for a management interface module **708**. The management interface module **708** is operable to provide a graphical user interface for entering and accessing debug management commands **710**. The management interface module **708** provides assistance on parameters and command names needed for entering the debug management commands **710**. In step **772**, the management interface module **708** provides a set of debug management commands in a graphical user interface (GUI) and in step **774**, receives the management commands through the GUI, such as a command line interface or other type of GUI. In step **776**, the management command is processed by the chassis supervisor module **420** of the CMM **150** of network node **110***a*, though other management modules or applications may process the debug management command **710** in addition to or alternatively from the chassis supervisor module **420** of the CMM **150**. In step **778**, the chassis supervisor module **420** informs management of command execution to prevent interference with other tasks and prevent acceptance of other management commands before completion of current command execution.

The remote debugging module **702** enhances debugging of application modules in remote network nodes by providing access to the remote network nodes without the need of direct console access. It helps to automate complex operations and deliver a user friendly interface and minimize impact on current running application modules.

The network nodes **1110** in a virtual chassis system **100** are treated as a single logical device with a common virtual chassis MAC address. As such, external nodes **112** are operable to actively forward traffic on all the links of a VC-LAG **114** operatively coupled to two or more network nodes **110**. This feature enables multiple homing of the external nodes **112** to the network nodes **110** without requiring spanning tree protocols between the external nodes and network nodes while still facilitating a carrier-grade detection and convergence time to edge uplink failures as well as network node **110** failures. Another advantage of the active forwarding mode of all the VC-LAG **114** uplinks to the virtual chassis system **100** is increased efficiency of the use of bandwidth of the VC-LAG **114** links. The virtual chassis system **100** thus provides a resilient network between network nodes having one or more different types of node architectures in one or more different types of network topologies.

As may also be used herein, the term(s) "operably coupled to", "coupled to", and/or "coupling" includes direct coupling between items and/or indirect coupling between items via an intervening item (e.g., an item includes, but is not limited to, a component, an element, a circuit, and/or a module) where, for indirect coupling, the intervening item does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As may further be used herein, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two items in the same manner as "coupled to".

As may even further be used herein, the term "operable to" or "operably coupled to" indicates that an item includes one or more of power connections, input(s), output(s), etc., to perform, when activated, one or more its corresponding functions and may further include inferred coupling to one or more other items. As may still further be used herein, the term "associated with", includes direct and/or indirect coupling of separate items and/or one item being embedded within another item, or one item configured for use with or by another item. As may be used herein, the term "compares favorably", indicates that a comparison between two or more items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

As may also be used herein, the terms "processing module", "processing circuit", and/or "processing unit" may be a single processing device or a plurality of processing devices. Such a processing device may be a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on hard coding of the circuitry and/or operational instructions. The processing module, module, processing circuit, and/or processing unit may be, or further include, memory and/or an integrated memory element, which may be a single memory device, a plurality of memory devices, and/or embedded circuitry of another processing module, module, processing circuit, and/or processing unit. Such a memory device may be a read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that if the processing module, module, processing circuit, and/or processing unit includes more than one processing device, the processing devices may be centrally located (e.g., directly coupled together via a wired and/or wireless bus structure) or may be distributedly located (e.g., cloud computing via indirect coupling via a local area network and/or a wide area network). Further note that if the processing module, module, processing circuit, and/or processing unit implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory and/or memory element storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry. Still further note that, the memory element may store, and the processing module, module, processing circuit, and/or processing unit executes, hard coded and/or operational instructions corresponding to at least some of the steps and/or functions illustrated in one or more of the Figures. Such a memory device or memory element can be included in an article of manufacture.

The present invention has been described above with the aid of method steps illustrating the performance of specified functions and relationships thereof. The boundaries and sequence of these functional building blocks and method steps have been arbitrarily defined herein for convenience of description. Alternate boundaries and sequences can be defined so long as the specified functions and relationships are appropriately performed. Any such alternate boundaries or sequences are thus within the scope and spirit of the claimed invention. Further, the boundaries of these functional building blocks have been arbitrarily defined for convenience of description. Alternate boundaries could be defined as long as the certain significant functions are appropriately performed. Similarly, flow diagram blocks may also have been arbitrarily defined herein to illustrate certain significant functionality. To the extent used, the flow diagram block boundaries and sequence could have been defined otherwise and still perform the certain significant functionality. Such alternate definitions of both functional building blocks and flow diagram blocks and sequences are thus within the scope and spirit of the claimed invention. One of average skill in the art will also recognize that the functional schematic blocks, and other illustrative blocks, modules and components herein, can be implemented as illustrated or combined or separated into discrete components, application specific integrated circuits, processors executing appropriate software and the like or any combination thereof.

The present invention is described herein, at least in part, in terms of one or more embodiments. An embodiment is described herein to illustrate the present invention, an aspect thereof, a feature thereof, a concept thereof, and/or an example thereof. A physical embodiment of an apparatus, an article of manufacture, a machine, and/or of a process that embodies the present invention may include one or more of the aspects, features, concepts, examples, etc. described with reference to one or more of the embodiments discussed herein. Further, from figure to figure, the embodiments may incorporate the same or similarly named functions, steps, modules, etc. that may use the same or different reference numbers and, as such, the functions, steps, modules, etc. may be the same or similar functions, steps, modules, etc. or different ones.

Unless specifically stated to the contra, signals to, from, and/or between elements in a figure presented herein may be analog or digital, continuous time or discrete time, and single-ended or differential. For instance, if a signal path is shown as a single-ended path, it also represents a differential signal path. Similarly, if a signal path is shown as a differential path, it also represents a single-ended signal path. While one or more particular architectures are described herein, other architectures can likewise be implemented that use one or more data buses not expressly shown, direct connectivity between elements, and/or indirect coupling between other elements.

The term "module" is used in the description of the various embodiments of the present invention. A module includes a processing module (as described above), a functional block, hardware, and/or software stored on memory operable to perform one or more functions as described herein. Note that, if the module is implemented via hardware, the hardware may operate independently and/or in conjunction with software and/or firmware. When a module is implemented as software stored in memory, the module is operable to use a processing module or other hardware to execute the software stored in memory in the module to perform the functions as described herein. A module described herein may include one or more sub-modules, each of which may be one or more modules, be incorporated into one or more other modules or include one or more other modules.

While particular combinations of various functions and features of the present invention are expressly described herein, other combinations of these features and functions are likewise possible. The embodiment described herein are not limited by the particular examples described and may include other combinations and embodiments.

What is claimed is:

1. A network node in a virtual chassis system, comprising:

a plurality of virtual fabric links (VFLs) operably coupled between the network node and a plurality of other network nodes in the virtual chassis system;

a control management module operable to generate a topology database that includes a chassis identification and local address of a master network node in the virtual chassis system and chassis identifications and local addresses of the plurality of other network nodes in the virtual chassis system, the control management module operable to:

adopt the local address of the master network node in the virtual chassis system as a virtual chassis address of the network node for addressing of the virtual chassis system by external nodes; and

at least a first network interface module operable to:

store one or more address tables that include destination addresses associated with hardware device information of the plurality of other network nodes in the virtual chassis system;

receive an incoming packet on an external port interface, wherein the incoming packet includes a first destination address;

determine from the one or more address tables destination hardware device information of one of the plurality of other network nodes in the virtual chassis system associated with the first destination address, that includes access a first forwarding table having a list of destination address entries and associated hardware device information of the one of the plurality of other network nodes in the virtual chassis system associated with the first destination address, wherein the associated hardware device information of the one of the plurality of other network nodes includes a chassis identification of the one of the plurality of other network nodes;

access a second address table that includes a list of chassis identifications and associated VFL identifiers, wherein the associated VFL identifiers identify at least one VFL for forwarding a packet to one of the plurality of other network nodes identified by the chassis identification;

generate a packet with pre-pended header from the incoming packet, wherein the pre-pended header includes the destination hardware device information of the one of the plurality of other network nodes in the virtual chassis system; and

transmit the packet with pre-pended header over one of the plurality of virtual fabric links to the one of the plurality of other network nodes in the virtual chassis system.

2. The network node of claim **1**, wherein the at least a first network interface module is operable to:

determine from the second access table a VFL identifier associated with the chassis identification of the one of the plurality of other network nodes in the virtual chassis system associated with the first destination address; and

transmit the packet with pre-pended header over the one of the plurality of virtual fabric links associated with the VFL identifier to the one of the plurality of other network nodes in the virtual chassis system associated with the first destination address.

3. The network node of claim **2**, wherein the first network interface module comprises:

a switching circuit that includes a plurality of external port interfaces, wherein the first network interface module receives the incoming packet on one of the plurality of external port interfaces; and

a queuing circuit that includes a queue management module.

4. The network node of claim **3**, wherein the switching circuit further includes:

a pre-pended packet header interface (PPHI) operable to generate the packet with pre-pended header, wherein the pre-pended header includes the destination hardware device information.

5. A network node in virtual chassis system, comprising:

a plurality of virtual fabric links (VFLs) operably coupled between the network node and a plurality of other network nodes in the virtual chassis system;

a control management module operable to generate a topology database, wherein the topology database includes a chassis identification and local address of a master network node in the virtual chassis system and chassis identifications and local addresses of the plurality of other network nodes in the virtual chassis system, the control management module operable to:

adopt the local address of the master network node in the virtual chassis system as a virtual chassis address of the network node for addressing of the virtual chassis system by external nodes when the network node is operating in a virtual chassis mode; and

at least a first network interface module operable to:

receive a packet with a destination address from an external node;

access one or more forwarding tables to determine hardware device information of one of the plurality of other network nodes associated with the destination address, wherein the hardware device information includes a VFL identifier of at least one VFL coupled to the network node and the one of the plurality of other network nodes associated with the destination address; and

transmitting the packet over the at least one VFL coupled to the network node and the one of the plurality of other network nodes associated with the first destination address.

6. The network node of claim **5**, wherein the control management module is further operable to:

initiate a first configuration module when the network node is operating in a virtual chassis mode; and

initiate a second configuration module when the network node is operating in a standalone mode.

7. The network node of claim **6**, wherein the control management module is further operable to:

transition from a standalone mode to a virtual chassis mode by reconfiguring parameters of the hardware device information and initiating the first configuration module.

8. The network node of claim **5**, wherein the control management module is further operable to:

receive a remote debug management command to redirect an output of a process in response to a debug function in the network node;

store a standard output descriptor of the process;

redirect the output of the process in response to the debug function to a selected destination; and

restore the standard output descriptor of the process.

9. A method for a network node in a virtual chassis system, wherein a plurality of virtual fabric links (VFLs) are operably coupled between the network node and a plurality of other network nodes in the virtual chassis system comprising:

generating a topology database that includes a chassis identification and local address of a master network node in the virtual chassis system and chassis identifications and local addresses of the plurality of the other network nodes in the virtual chassis system;

adopting the local address of the master network node as a virtual chassis address of the network node for addressing of the virtual chassis system be external nodes when the network node is operating in a virtual chassis mode;

storing one or more address tables that include destination addresses associated with hardware device information of a plurality of other network nodes in the virtual chassis system;

receiving an incoming packet on an external port interface, wherein the packet includes a first destination address;

determining from the one or more address tables destination hardware device information of one of the plurality of other network nodes in the virtual chassis system associated with the first destination address;

generating a packet with pre-pended header from the incoming packet, wherein the pre-pended header includes the destination hardware device information of the one of the plurality of other network nodes in the virtual chassis system; and

transmit the packet with pre-pended header over one of the plurality of virtual fabric links to the one of the plurality of other network nodes in the virtual chassis system.

10. The method of claim **9**, wherein determining from the one or more address tables destination hardware device information includes:

accessing a first forwarding table, wherein the first forwarding table includes a list of destination address entries and associated hardware device information of one of the plurality of other network nodes in the virtual chassis system associated with the first destination address.

11. The method of claim **10**, wherein the destination hardware device information of the one of the plurality of other network nodes in the virtual chassis system associated with the first destination address includes a chassis identification of the one of the plurality of other network nodes.

12. The method of claim **11**, further comprising:

accessing a second address table, wherein the second address table includes a list of chassis identifications and associated VFL identifiers, wherein the associated VFL identifiers identify at least one VFL for forwarding a packet to one of the plurality of other network nodes identified by the chassis identification.

13. The method of claim **12**, further comprising:

determining from the second access table a VFL identifier associated with the chassis identification of the one of the plurality of other network nodes in the virtual chassis system associated with the first destination address; and

transmitting the packet with pre-pended header over the one of the plurality of virtual fabric links associated with the VFL identifier to the one of the plurality of other network nodes in the virtual chassis system associated with the first destination address.

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